U.S. Mines, Bureau

Bulletin 25
Pt. 1.

DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
JOSEPH A. HOLMES, DIRECTOR

MINING CONDITIONS
UNDER THE
CITY OF SCRANTON, PA.

REPORT AND MAPS

BY

WILLIAM GRIFFITH AND ELI T. CONNER

WITH A PREFACE BY JOSEPH A. HOLMES AND A CHAPTER
BY N. H. DARTON

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PREFACE.

By Joseph A. Holmes.

The perpetuation of the supply of anthracite coal in Pennsylvania is a national as well as a State problem. Any investigation that shows how larger percentages of this coal may be saved in mining, without excessive cost, and without dangerous subsidence of the overlying surface ground, has a national as well as a local interest.

Messrs. Conner and Griffith, who conducted the investigations described in this report largely for the city of Scranton, are consulting engineers for the Bureau of Mines for investigations similar to those they have already made in connection with their Scranton work; and this report is published by the bureau in response to numerous requests, because of the fact that the information it contains will prove useful in the general solution of similar problems in many of the country's coal fields.

A study of the accompanying maps will show that the city of Scranton is underlain by 11 separate beds of coal, varying in thickness from 2 to 24 feet. It is estimated that before mining operations were begun these beds of coal contained underneath the present city limits of Scranton 600,000,000 tons of coal. The 27 collieries operating within the city limits, working independently of each other, had excavated and removed, up to March, 1911, an aggregate of 198,000,000 cubic yards of coal and accompanying rock, or 3,000,000 cubic yards more than the total amount of material excavated and to be excavated by the United States in constructing the Panama Canal. This fact illustrates something of the magnitude of the problem that the city of Scranton, with the aid of these engineers and of a special commission or advisory board, has undertaken to solve. The excavation has included 177,000,000 tons of coal and 44,000,000 tons of rock and accompanying refuse. This leaves about 420,000,000 tons of coal still to be removed.

As a result of other investigations and of experience in adjacent anthracite mines, Messrs. Conner and Griffith and the advisory board of engineers have advised that, as far as may be necessary to prevent dangerous surface subsidence, the spaces remaining beneath the

city of Scranton from the excavation of the above-described material should be filled with sand and other materials by flushing or other processes. This operation is expensive, but it is believed to be not beyond the reach of what is practicable, nor in excess of the value of the coal that may be removed and the amount of damages that may result from the caving in of the surface if such a plan is not carried out.

No one realizes so fully as do the authors of this report the need of additional tests and other investigations before the data now presented by them can be fully accepted as sufficient for all purposes in the solution of the problem; and it is expected that at some early date a more extensive series of similar tests can be made by the Bureau of Mines under the supervision of Messrs. Conner and Griffith on a larger scale and under a greater variety of conditions.

The field examinations made for the Bureau of Mines by N. H. Darton, which are described briefly in a chapter of this bulletin and will be discussed at length in a bulletin to be published later, indicate the extent and distribution of the sands, gravels, and other materials in the Scranton-Wilkes-Barre district available for flushing purposes if further tests indicate their relative merits; and it is expected that the relative merits of these different materials will soon be tested under such conditions as will furnish the desired information.

MINING CONDITIONS UNDER THE CITY OF SCRANTON, PA.

By William Griffith and Eli T. Conner.

LETTER OF TRANSMITTAL.

To the honorable Mayor and Council of the City of Scranton, and to the Board of Control of the Scranton School District:

Gentlemen: In rendering to you the following report upon the mining conditions under the city of Scranton, with observations and recommendations for the amelioration of the same, we feel that an apology is due for the voluminous proportions of the document. We trust, however, that you will consider the magnitude of the subject, and the manifest necessity under the circumstances of sacrificing brevity for clearness.

We have considered all the phases of the question in hand as fully and thoroughly as possible, having not only exhausted all the sources of present information available to us, but having made many tests and experiments as to the strength of materials and the efficiency of roof-supporting devices, both those at present in use and those originated by us. We may, therefore, perhaps be pardoned for felicitating ourselves with the consciousness that the whole question has been investigated and is herein considered with all the completeness which our ability and limitations would permit.

We desire to express our appreciation of the pleasant and courteous manner in which all the mining companies, including managers, superintendents, and inside officials, and the officials of the Fritz engineering laboratory of Lehigh University, have assisted us during the progress of the investigation, for without this cordial cooperation this report could not have been submitted in its present completeness. Our acknowledgments are also due to and on account of the treatment accorded us by the officials of the city and board of control, by the press and the public, and to Mr. S. N. Callender, for the use of his copy of the city atlas. Also to the members of the advisory board, for the care and enthusiasm with which they have considered this report, and for their practical suggestions, which are incorporated herein.

Very respectfully,

Wm. Griffith,
Eli T. Conner.

Scranton, Pa., *March 20, 1911.*

SUMMARY.

We would summarize our findings as follows:

The report is accompanied by plates which present a full set of plans of the city of Scranton and the mine workings thereunder, and also cross sections showing the positions of the several beds of coal and the intervening strata. From these plates one can readily determine, at almost any given point, the depth of the coal below the surface, the thickness of the beds, and the thickness of the intervening strata, since all of the plans are drawn to scale. These plates should be carefully studied in connection with the report and tables. As provided for in our contract, these plans are based upon information obtained from the maps, records, and data loaned to us by the several mining corporations, the Pennsylvania geological survey of 1885, and from our own personal investigations and measurements.

It will be noted that the coal basin underlying the city is wide and comparatively shallow, so that the coal beds and the intervening strata are comparatively flat, by reason of which fact the artificial pillars that may be inserted are not at all liable to slip or move on account of the dip of the seams. The only part of the coal measures underlying this city where there is an excessive dip is along the West Mountain, where pitches as steep as 50° are found. There is only a small part of the surface underlain by such pitching seams that carries important improvements, namely, in the vicinity of No. 23 School and what is locally known as the "Notch."

After about 40 days of careful inspection of underground conditions at all of the collieries operating within the city limits, we find that the total quantity of coal and refuse that has been extracted under the city of Scranton is about 221,000,000 tons.

There has been produced for market from the 27 collieries, 177,000,000 tons of coal.

The space excavated under the city is about 198,000,000 cubic yards. The total estimated excavation by the United States for the Panama Canal is 195,323,000 cubic yards.

It must not be understood that the hole from which the above material has been taken is still open. It is, of course, impossible to say what percentage of the space excavated remains open, but we would express the belief that it does not exceed one-half of the original, due to the numerous squeezes and cave-ins that have occurred.

After spending more than 40 days' time studying maps, after testing various materials used and considered for roof support in the

mines, and after tabulating and considering the information gained by these investigations, the conclusions we have reached are as follows:

Although some other devices are locally useful, the only method that combines the necessary qualities of strength, ease of application, and reasonable cost is filling the underground openings by what is known as the "flushing" method, using for flushing culm, sand, crushed rock, and other fine material that can be washed into the mines with water. This method was originated in the anthracite region of Pennsylvania, and has been extensively adopted in European mines, where, at great expense, sand, loam, and crushed rock are flushed into the mines following the removal of the coal by the longwall method of mining.

The tables and estimates of cost contained in the body of the report give in detail the results of our investigations and conclusions.

We therefore offer as our only recommendation that the flushing method be adopted, under the plans and specifications contained in the body of the report and in plates 1 to 24. From the report the following general conclusions are drawn:

1. Speaking broadly, the surface of the city can be supported by the methods recommended, and at a cost not in any sense prohibitory when considered with relation to the value of the property and operations for which support is absolutely essential.

2. Although in our judgment there are points in the city, as indicated in the detailed report, where at the present time there is distinct and immediate danger to life and property, yet the total area immediately threatened constitutes but about 15 per cent of the entire area of the city, and the danger is mainly from workings in surface beds.

3. On the west side the beds of the middle series are thick and close together, and the pillars are not columnized, creating a dangerous situation where the workings have not been closed by previous caves. Particular areas thus threatened can not be definitely specified on account of the inaccessibility of much of the mined-over area. Detailed investigation should be made of the portions of the mines not already closed. Relatively, we do not believe that a large part of the territory mentioned is threatened on account of so much ground having been already closed by caves.

Special attention is called to the conditions under schools Nos. 13, 23, and 29. They should be attended to promptly.

The lower series of beds, namely, the three Dunmores, are so thin and so far below the surface that with the usual system of mining we do not think they constitute a serious menace to the improvements on the surface, except along the margin of solid blocks of unmined coal and near the outcrops. In the deep-lying parts of the Dunmore beds we believe these solid blocks should be mined.

4. It would seem, therefore, to be not only the part of wisdom, but absolutely obligatory, to immediately commence supporting the points menaced, and thereupon proceed upon a general policy of giving support to the entire area of the city, for it must be borne in mind that with the mining activities that are constantly going on other and additional points of danger are not only liable to, but in all probability will, develop with each passing year—it might almost be said with each passing month.

5. Where the owner of the surface has undoubted right to the support thereof by coal pillars, in our opinion he could permit the removal of such pillars; the value thereof would under average conditions pay for such artificial support as we have recommended, if it be assumed that the pillars were mined and the support constructed by the same operating company. This observation, however, is based upon the assumption that in such case the operating company is one of the large transportation companies, inasmuch as although there might not be a profit in the immediate transaction of mining the pillars and installing the support, there would, of course, be a profit to such companies in carrying the coal to market.

6. Culm flushing should be used only in coal beds having light cover, up to 200 to 500 feet, according to the settlement expected. But sand, being four or five times as strong as culm, is better, and, being suitable for filling all beds under Scranton, is to be preferred.

7. We believe that the conclusions adduced from the tests made, and the calculations and tabulations based thereon, are reasonably reliable; yet we desire to record the opinion that there are conditions existing in the mines to which they might not apply. Such might be the case, for instance, in localities where several beds of coal are separated by thin strata of shale and slate or even sandstone, and the pillars in the two or more beds are not over one another, and it is proposed to reclaim all or any part of the pillars.

Even though an application of the above-mentioned tables might appear to fit the conditions, we believe that the only permissible procedure would be to first fill with flushed material all of the openings in the lowest bed of the series, and then fill upward until all the beds are filled, care being taken to have the flushed areas over one another. After all of the openings in all of the beds have been filled the pillars in the uppermost bed may be attacked, and the space occupied by each pillar filled as soon as the pillar is removed. No pillar reclamation should be permitted in any of the other beds until all of the pillars in the upper bed have been removed and the overburden has come to rest on the flushed material; after which the pillars in the next lower seam may be attacked and handled in like manner.

8. Harmonious plans and procedure between the coal companies, the city, the school authorities, and the public are essential to the

successful carrying out of any relief measures that are herein or may be hereafter suggested. Some facts that should be evident to all are that the prosperity of the city and of the community is to a large extent dependent upon the coal companies; that drastic laws or regulations that may curtail the mining of coal will necessarily react on the prosperity of the community; and that any ameliorating plans or compromises which it may be possible to effect between the city and the mining companies tend to prolong the life of the mining industry in Scranton and vicinity, and should be promoted.

It should therefore be the aim of all interested in mine-cave protective measures and of the companies operating the mines to adopt plans that will best conserve the welfare of all interested.

The expenditure for the work would of course be distributed over many years, the relief measures being applied at the points most in need of protection and as rapidly as proper arrangements could be effected and the necessary details, surveys, etc., prepared.

For the businesslike carrying out of the plans suggested it is recommended that a protective commission be established, consisting of not less than three nor more than five men, representing the city authorities, the school board, and the coal companies—this commission to have full and complete authority for the execution of the plans, and to be approved by the proper legal action. The commission should employ an engineer who should devote all his time to the service as active manager of the work.

THE REASON WHY.

The occasional mine caves or settlements in various parts of Scranton during the past years had long caused more or less public concern, until finally popular sentiment was brought to a focus by the settlement in Hyde Park, on August 29, 1909. This subsidence seriously damaged public school No. 16 and much other surrounding property; and, if it had occurred while school was in session, might have been the cause of loss of life.

Immediately following this event committees of councils, board of control, and board of trade took action in an endeavor to discover the immediate physical causes of the caving, as well as the legal responsibility therefor; and after much consideration, the former mayor, Hon. J. B. Dimmick, who was called in consultation with the joint committee, proposed the plan as set forth below and quoted from his final report, to wit:

To the joint committee of mine caves of select and common councils and of the board of control, Benton T. Jayne, chairman:

Gentlemen: I beg leave to herewith make report of what I have been able to accomplish in pursuance of your instructions looking to the selection of an engineer to be employed by the city and the board of control for the purpose of making a study of

the physical aspect of the entire mine-cave problem as it affects our city, and to make a report thereon together with such recommendations as would seem fitting and practicable.

Shortly after I received your instructions I laid the entire situation before John Hays Hammond, the well-known engineer, and he at once not only became deeply interested in the problem but offered his aid and assistance without compensation, direct or indirect, being moved simply by a willingness to perform public service.

After much thought and conversation with the gentlemen whose names are hereinafter given, the following definite plan has been worked out and awaits but acceptance upon the part of the city government and the board of control.

PLAN.

An advisory board has been formed consisting of five well-known engineers, with power to add to their number, namely: John Hays Hammond, D. W. Brunton, R. A. F. Penrose, jr., Lewis B. Stillwell, and W. A. Lathrop, this board having all agreed to act without compensation.[a] After a careful investigation of the necessary qualifications of the engineers that would make the actual study upon the ground, they suggested the names of Eli. T. Conner, of Philadelphia, Pa., and William Griffith, of Scranton, Pa., Mr. Conner having had considerable experience in anthracite-mining operations, and Mr. Griffith being especially informed as to the geological formation of this section. These two engineers to be employed by the city and the board of control, and upon the filing of their report, the same to be carefully considered and passed upon by the advisory board.

In order that the matter might be in complete form for your consideration, I secured from the two engineers, as recommended, a definite proposition, which is herewith incorporated in extenso:

SCRANTON, PA., *May 25, 1910.*

Hon. J. BENJ. DIMMICK, *Scranton, Pa.:*

As a result of our conference with you yesterday, in accordance with your request made at that time, we respectfully submit the following:

Of course, it is recognized by everybody that the situation is serious regarding the mining conditions under portions of the city of Scranton, and the proposition of proecting the whole city can best be met by a frank recognition of the varying conditions that undoubtedly exist, certain sections of the city being really in danger, while others are, practically speaking, not menaced. While our proposed report would be general in character, and intended to cover the entire city, yet it would properly be especially concerned with those sections of the city that are immediately threatened.

It seems to us that what is most necessary at the present time is more accurate knowledge of the physical conditions which now prevail, and we would suggest a report based upon the results of a careful study of such physical conditions as they at present exist in the mines under the city of Scranton; this report to be general in its nature. We would group together the various similar conditions in several classes, to each of which similar remedies or lack of remedy might apply, with suggestions not only as to remedies but also as to the approximate cost thereof under certain ascertained conditions. We should expect to also include in said report such general observations and recommendations touching the entire situation as would seem to be justified by our inspection and study thereof. The completeness and value of any such report would depend in a large measure upon the assistance and cooperation tendered us by the several mining companies who are now operating under the city and of the city and school authorities.

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[a] The advisory board subsequently included the following additional members: Dr. H. S. Drinker, president of Lehigh University; Dr. J. A. Holmes, director of the Bureau of Mines; Prof. J. F. Kemp, Columbia University; Prof. J. F. McClelland, Yale University; and Prof. H. L. Smyth, Harvard University.

It is to be distinctly understood that such proposed report and study of the situation existing under Scranton would be based upon such information as might be obtained from the second geological survey and from such other maps of the various coal-mining companies and the city and school authorities, to which access could be obtained for the engineers, and from such personal inspection of accessible portions of the mines as, in our judgment, shall be necessary. We would, however, give expression to our belief that such surveys are sufficiently accurate and reliable as a basis for the general conclusions that the report will be expected to set forth.

It seems to us that the information to be secured through such a report would be the first requisite to a subsequent detailed investigation and application of any remedies which might be suggested for the amelioration of the mining conditions under this city.

Yours, respectfully,

(Signed) WM. GRIFFITH,
ELI. T. CONNER,
Mining Engineers.

It therefore remains but for the community, through its city government and the board of control, to employ these two engineers at the price stipulated in order to receive a general report upon the cave problem that should command the respect and the confidence of all parties interested, not only because it will have been prepared by engineers selected by a board composed of experts of national reputation, but also because the very findings of such engineers would, in their turn, be submitted to and reported upon by that same advisory board. In short, the community would then be provided with information as to facts and opinions as to remedies that would form solid ground for both future deliberations and future activities.

I can not refrain from suggesting, assuming the acceptance of this most unselfish offer upon the part of men of high professional equipment and without personal interest in the welfare of Scranton, that, simultaneously with the enactment of the necessary legislation to carry into effect this plan, there should be official appreciation of their proffered assistance.

Respectfully submitted.

J. BENJ. DIMMICK.

Certified copy.

EVAN R. MORRIS, *City Clerk.*

SEPTEMBER 15, 1910.

GEOLOGY.

The city of Scranton occupies the surface overlying the whole width (5 miles) of the Lackawanna coal field, and extends about 5 miles up and down the valley. The central part of the city is over the center of the coal basin, while the margin of the basin on the East and West Mountains nearly coincides with the city line along those hills.

The floor of this coal basin is formed by the hard Pottsville conglomerate or "pudding stone," which comes to the surface on the mountain sides east of Roaring Brook, and dipping down under the surface in the form of a deep trough or basin passes under the central part of the city at a depth of several hundred feet, and again reaches the surface on the flanks of the West Mountain. Passengers on the Laurel Line can note this conglomerate on both sides of the Roaring Brook ravine and at the stone quarry on the east near the switch where the Dunmore branch leaves the main line.

It is the conglomerate that forms the roof of the Lackawanna tunnel at Nay Aug, and is again cut by this railroad on the west side of the valley, at Leggetts Creek Gap.

As before stated, this rock forms the floor of the coal basin. No coal exists below it; therefore all the coal under the city of Scranton is to be found in the rocks which fill this trough or basin and overlie the Pottsville conglomerate. The coal is deposited in parallel layers or beds, known locally as "coal veins," that are approximately parallel to the conglomerate floor, and lie deepest in the central part of the basin. They extend with persistence and considerable regularity from outcrop to outcrop, except where they were removed with other rocks during the surface erosion of past ages.

In all, there are 11 principal coal beds under this city, known by names as follows, beginning with the highest:

The Eight-Foot coal bed, which is present only in two small areas or islands under the highest part of the Hyde Park hill.

The Five-Foot and Four-Foot beds, which are only in the hill top on the west side from Dodge to Marvine, above the level of the Lackawanna River.

The Diamond and Rock beds, which are on the west side only of Lackawanna River, under Bellevue, Hyde Park, Providence, and parts of Keyser Valley.

The Big or Fourteen-Foot and New County beds, which extend under the whole west side, and also become surface beds on the east side at the National colliery, near the south line of the city; also under the central city and hill section, nearly to the Moses Taylor Hospital.

The Clark, Dunmore No. 1, Dunmore No. 2, and Dunmore No. 3 beds, which extend under the whole city from Nay Aug Park to the West Mountain.

For the thicknesses of these several beds, the distances between them, and their relative positions in the coal measures, the reader is referred to the columnar section sheets contained in Plates 1 to 24 of this report.

HISTORY.

EARLY DEVELOPMENTS.

The late Dr. B. H. Throop reported to an industrial convention at Tunkhannock, in the year 1842, that the Lackawanna Valley from Archbald to Pittston "contains upward of one hundred coal mines opened, and many of them are made at present a source of profit both from domestic and foreign markets. There are sent some five or six thousand tons of coal annually by sledges and wagons to the States of New York and New Jersey, in exchange for salt, plaster, etc."

In 1841 the first furnace of the Lackawanna Iron & Coal Co. was filled and fired, and though this effort to manufacture iron from local ores proved a total failure, it nevertheless gave a decided impetus to the coal-mining industry of this locality. Subsequently iron ore and limestone were brought from a distance, and anthracite was successfully used for smelting iron. Since this beginning the coal industry of Scranton has continuously flourished until the present.

The mines worked by the iron company in 1841 were on both sides of Roaring Brook. The Clark bed was worked near the viaduct; later the Dunmore beds were worked near the site of the present Laurel Line power house by what were known as the Rolling Mill drifts. For several years these were the principal mines in Scranton.

In 1851 the Lackawanna & Western Railroad was built from Scranton to connect with the Erie road at Great Bend. The Delaware & Cobbs Gap road (chartered in 1849) was merged with the Lackawanna, and in 1856, under the name of the Delaware, Lackawanna & Western Railroad, was built through from Scranton to the Delaware River. In 1858 the Lackawanna & Bloomsburg road was built. Equipped thus with new and permanent outlets for its resources, the mining industry of the valley and the city advanced with rapid strides.

About 1852 the Diamond mines were opened. In 1854 the Rockwell mine at Leggetts Gap, and the Bellevue colliery were opened. The opening of numerous other coal operations followed in rapid succession.

MINING METHODS.

The room and pillar system of mining was adopted in these old mines, and has been continued in all the mining of the region to the present time. This method consists, briefly, in driving an airway and a gangway about 15 feet apart and parallel in the coal bed. On the high side—that is, to the rise—chambers or rooms are driven parallel to each other and at right angles to the gangways. The rooms are about 30 feet wide and are separated by partitions about 15 feet in thickness called pillars. The coal production of the mine is mainly taken from the contents of the rooms; the pillars, which comprise approximately one-third of the coal, are left to support the surface. This practice of leaving one-third of the coal for surface support was adopted at the start, and was found sufficient for the comparatively light overburden to be sustained in the mining of the beds near the surface. It has been continued as an empirical rule with little variation, in the deeper mining under the city, without reference to the weight on the pillars or the strength of the coal.

In the past the several beds of each mine were worked independently of each other and no attempt was made to regulate the size,

position, and distribution of pillars aside from the one-third rule. Consequently, the pillars are not columnized; in other words, they are not exactly over each other. Many of the thick beds of the middle measures under the Hyde Park and Providence sections are close together. Therefore the pillars in these thick beds, not being columnized, have a decided tendency to crush through the interval between the beds, the pillars of an upper bed settling into the excavations or rooms of the lower workings.

Another feature that should be brought out in this historical sketch of early mining in Scranton is that the universal practice in the old days was to mine only the best, thickest, and most accessible coal beds, and also only the profitable parts of each bed, and to leave unmined, as refuse, the parts which for one cause or another were found more expensive to work. Therefore, in these latter days some of the coal beds already mined over and ready to be abandoned have been found to carry rider coal above or bottom coal below, which can be removed at a profit. And, therefore, for the past few years the total production from several beds has been from such remining of top and bottom coal. This remining, of course, leaves the pillars from 2 to 6 feet taller than they were before for the same horizontal area, consequently the pillars are much weaker and less able to support the overburden.

In consequence of the several conditions related above there have been from time to time numerous and more or less serious caves or subsidences of the surface, principally on the west side, which have caused some damage to surface property, but no loss of life. In every instance the damage has been speedily repaired and temporarily forgotten. The accumulated result of these repeated subsidences has probably left certain parts of the surface in that section of the city in more stable condition than they were before. This phase of the subject, however, will be considered in a subsequent chapter.

STATISTICS OF COAL PRODUCTION.

The following statistics of the coal-mining industry in Scranton are based upon the result of the surface and underground investigations made by us, and from our inspection of the mine maps, taken in conjunction with the annual production of coal as shown in the published statistics contained in the reports of the State mine inspectors.

TABLE 1.—*Total production of coal mined under the city of Scranton, 1841–1910.*

Year.	Production.	Year.	Production.
	Long tons.		*Long tons.*
1841–1872	22,760,000	1892	3,921,894
1872	2,155,647	1893	3,992,640
1873	2,570,081	1894	3,614,488
1874	1,630,158	1895	4,042,677
1875	2,312,580	1896	3,882,848
1876	1,572,033	1897	3,935,907
1877	1,818,867	1898	3,527,826
1878	1,732,782	1899	4,308,338
1879	2,670,629	1900	4,381,573
1880	2,477,285	1901	6,041,215
1881	3,002,761	1902	4,345,310
1882	2,996,795	1903	6,578,771
1883	3,280,001	1904	6,202,694
1884	3,038,291	1905	6,257,380
1885	3,261,483	1906	6,163,199
1886	3,092,069	1907	6,948,258
1887	4,054,109	1908	6,336,726
1888	4,474,419	1909	5,915,774
1889	3,724,127	1910	6,000,000
1890	4,032,073		
1891	3,795,911		176,839,619

TABLE 2.—*Statistical table of coal mining.*

Coal beds.	Average thickness of beds.	Original area before mining.	Area mined over.	Area to be mined.	Approximate area of pillars.	Area of mine excavation.	Foot-acres mined over, including pillars.	Foot-acres excavated, excluding pillars.	Foot-acres to be excavated, leaving one-third for pillars.
	Feet.	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*			
Eight-foot	7.6	140	111	29	35	76	843	577	146
Five-foot	4.4	2,000	1,093	907	364	729	4,809	3,208	2,660
Four-foot	3.6	2,460	994	1,466	331	663	3,578	2,387	3,518
Diamond	9.4	4,160	3,562	598	1,187	2,375	33,495	22,325	3,746
Rock	5.2	4,500	3,000	1,500	1,000	2,000	15,600	10,400	5,200
Big	12.2	6,000	4,831	1,169	1,610	3,231	58,938	39,296	9,508
New County	6.0	5,360	1,549	3,811	516	1,033	9,294	6,198	15,244
Clark	6.7	7,860	6,040	1,820	2,013	4,027	40,468	26,981	8,130
Dunmore No. 1	3.0	7,500	690	6,810	230	460	2,070	1,380	13,620
Dunmore No. 2	4.0	9,630	2,533	7,097	844	1,689	10,132	6,756	14,194
Dunmore No. 3	3.3	8,500	1,573	6,927	524	1,049	5,191	3,462	15,240
	....	58,110	25,976	32,134	8,654	17,322	184,418	122,970	91,206

Total space excavated in the mines under Scranton .... cubic yards..	198,104,670
Total estimated excavation for Panama Canal .... do....	174,666,594
Total approximate tonnage of coal produced to January 1, 1911 .... long tons..	176,840,000
Total approximate tonnage of coal waste and mine refuse excavated, but not included in production .... long tons..	44,500,000
Average production per foot-acre excavated .... do....	1,440
Average production per foot-acre mined over .... do....	960
Number of collieries and mines operating under the city	27

PRESENT MINING CONDITIONS UNDER SCRANTON.

The following tabulated notes give in condensed form the actual conditions of the mining under the city and school properties at present, as found by your engineers during an extended underground inspection that lasted about 40 days.

In connection with these notes the plates accompanying this report should be well studied. These plates set forth in a more intelligible form than can possibly be shown by words the location and extent of the mining in all the coal beds under the city, and by plans, cross sections, columnar sections, etc., clearly indicate the geology and distribution of the beds throughout the measures.

Scranton Coal Co. collieries.

PINE BROOK COLLIERY.

(Works central city section from the river to Nay Aug and from Poplar Street to Beech Street.)

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
Eight-foot		Eroded	Eroded.
Five-foot		do	Do.
Four-foot		do	Do.
Diamond		do	Do.
Rock		do	Do.
Big	Technical High	Inaccessible, but reported flushed. (See Stevenson and Knight report.)	53 acres mined over. Depth, 30 to 50 feet (see sections on Pls. 2, 3, 4, and 5); thickness, 12 to 16 feet; pillars sound where observed; local falls; old workings mainly fallen and inaccessible.
	No. 33	Near outcrop; probably unminable or absent.	
	Central High	Partly mined and partly inaccessible; pillars sound; 8 iron posts and gob stoppings, behind which inaccessible; reported filled. (See Stevenson and Knight report.)	
New County		Not mined	Not mined; 3 feet thick.
Clark	No. 4	Pillars sound, as shown on maps; not much chipping; no evidence of disturbance.	584 acres mined over. Thickness, 7 to 12 feet, including 2 to 4 feet of impurities; depth, 150 to 200 feet. (See sections on Pls. 2, 3, 4, and 5). Character friable; pillars subject to chipping. Old workings between Gibson and and Ash Streets and from Capouse to Quincy Avenue show weakness due to weight, and indicate incipient squeeze. Old Iron Co. workings both sides Roaring Brook. North side bounded by Madison, Vine, and Clay Streets and the brook. South workings side lying between the brook and Pittston Avenue are inaccessible. The bed is near surface and thick, and old maps show very small pillar support.
	No. 9	Pillars sound and no disturbance.	
	No. 33	Pillars sound and undisturbed; chambers filled with dry ashes.	
	Technical High	Chambers large; all pillars small and weak; roof fallen in all chambers.	
	Central High	Pillars, as shown by maps, relatively small, and apparent weakness shown by chipping; gob piers built; flush pipe passes under and beyond school.	
	No. 36	Filled with water and inaccessible.	
Dunmore No. 1	No. 4	Chambers nearly filled with rock; pillars strong; conditions good.	349 acres mined over. Bed 4 to 5 feet thick; some places increased by top bench; bottom taken up for height; chambers partly filled with rock; general conditions good; depth, 200 to 270 feet (see sections on Pls. 1, 2, 3, 4, and 5).
	No. 9	Inaccessible on account of water; reported partly full of rock.	
	Technical High	Chambers nearly full of rock; pillars sound; conditions good.	
	Central High	Pillars large; only partly mined; conditions good.	
	No. 33	Chambers nearly filled; conditions good.	
	Nos. 35 and 36	Not mined.	

Scranton Coal Co. collieries—Continued.

PINE BROOK COLLIERY—Continued.

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
Dunmore No. 2	No. 4	Pillars sound; chambers three-fourths filled with gob rock; no disturbance.	852 acres mined. Bed 3 to 5 feet thick; 1 to 2 feet of bottom raised for height; chambers nearly filled with gob, except road in center; pillars strong and conditions generally good, except old Rolling Mill drift and slope both sides of Roaring Brook, where pillars are small and openings large. (See sections on Pls. 1, 2, 3, 4, 5, 18, 22, and 24.)
	No. 36	Pillars sound and large.	
	No. 9	Inaccessible on account of water. (See Stevenson and Knight report.)	
	No. 35	Pillars sound; conditions good. Now working.	
	Technical High	Roof falls prevented access; reported good; pillars and chambers partly filled.	
	No. 33	Pillars sound; chambers nearly filled; conditions good.	
	Central High	Partly mined only; Sanderson reservation to southward not yet mined.	
	No. 3	Now mining 5 feet 7 inches; raising 2 feet of bottom rock; coal pillars firm; chambers one-half filled with gob; conditions good.	
	No. 2	Old workings; recently unwatered; pillars small; rooms large; local falls; all quiet.	
Dunmore No. 3	No. 36	Pillars slightly chipped; otherwise strong, and as per map; three-fourths of space outside of roadway filled with gob; conditions good.	354 acres mined. Bed $2\frac{1}{2}$ to 5 feet thick, including 10 to 18 inches refuse; all chambers nearly filled with gob, except roadway in center; pillars strong and conditions generally good; depth, 300 to 350 feet (see sections on Pls. 1 to 24).
	Central High	Not now mined, but being extended; near-by workings three-fourths filled with gob; conditions good.	
	No. 33	Coal vein is faulty; thin and impure coal now worked; 3 feet top rock being taken down and workings being filled tight; conditions good.	
	Technical High	Inaccessible on account of water in adjacent workings; three-fourths filled with gob, except roads; conditions good.	
	No. 9	Pillars sound; chambers three-fourths filled outside of road; conditions good.	
	No. 4	Pillars strong; chambers filled, except road; conditions good.	

MOUNT PLEASANT COLLIERY.

(Works Hyde Park, from Lackawanna River to Keyser Creek, and between Lafayette and Pettibone Streets.)

Eight-foot	No. 18	School over outcrop of bed; bed not mined	33 acres mined. Depth, none at outcrop to 80 feet over center of area (see Pls. 14, 16, and 17); thickness, 8 feet 8 inches in center; 1 foot 5 inches refuse; all mined over, except stripping at outcrop, and abandoned; pillars standing in good condition.
Five-foot	do	Depth, 134 feet; openings filled with gob and falling fire clay; pillars reported standing firm, reinforced by this falling strata shaken by old squeeze in lower beds; present conditions fair	122 acres mined. Depth, none at outcrop to 200 feet (see sections on Pls. 14, 16, and 17); thickness, 5 feet 8 inches; includes 10 inches of bone at top; bed overlaid by 3 feet 5 inches of falling fire clay; all abandoned parts filled with falling fire clay; conditions fair.
Four-foot	do	Depth, 164 feet; pillars large and firm; rooms filled with rock	120 acres mined. Depth, see sections on Plates 14, 16, and 17; twin bed; top coal, 1 foot 10 inches; dividing rock, 6 to 7 feet; bottom coal, 3 feet; pillars sound; rooms filled with rock; conditions good.
Diamond	do	Mined, closed, abandoned, and inaccessible; depth, 280 feet	188 acres mined. Depth, see sections on Plates 14, 16, and 17; thickness about 10 feet; soft falling roof; workings formerly squeezed; [a] now closed by falling rock and inaccessible.
Rock	do	Mine abandoned and inaccessible account falls and old squeeze; depth, 315 feet.	190 acres mined. Depth, see sections on Plates 14, 16, and 17; thickness, 7 to 8 feet; 1 foot 2 inches refuse; reported pillars more than 33 per cent, but mine closed and inaccessible on account of squeeze. [a]
Big	do	Depth, 376 feet; workings inaccessible on account of roof falls, but pillars reported large and not crushed. (See maps.)	214 acres mined. Depth, see sections on Plates 14, 16, and 17; thickness, 14 feet 9 inches; 1 foot 7 inches refuse; workings partly open, but mainly closed by local falls and old squeeze. [a]
New County	do	Partly mined; rooms filled with rock; remaining coal soon to be mined, leaving usual pillars; depth, 418 feet.	208 acres mined. Depth, see sections on Plates 14, 16, and 17; thickness, 9 feet 8 inches, includes 1 foot 10 inches of refuse; open and accessible; rooms partly filled with gob; pillars sound, usual size; conditions good. [a]
Clark	do	Substantial pillars; some chipping; no indication of settlement; depth, 481 feet.	202 acres mined. Depth, see sections on Plates 14, 16, and 17; thickness, 6 feet 5 inches, includes 8 inches of refuse; rooms wide; pillars slightly air chipped, but otherwise sound; conditions fair.
Dunmore No. 1	do	Depth, 598 feet; only partly mined, by two gangways; no chambers.	32 acres mined. Depth, see sections on Plates 14, 16, and 17; thickness, 1 foot 4 inches to 1 foot 8 inches; vein too thin for profitable mining and now abandoned; openings filled with gob; conditions good.

[a] Surface subsidence may and often does occur where pillars are strong, and without much warning or crushing of pillars, if conditions exist such as those under Hyde Park, where many thick beds lie close together and the pillars in the several beds are not columnized; pillars of an upper bed are thus permitted to break through the intervening strata into the chambers or openings of an underlying bed.

Scranton Coal Co. collieries—Continued.

MOUNT PLEASANT COLLIERY—Continued.

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
Dunmore No. 2	No. 18	Depth, 612 feet; large pillars, sound and undisturbed; rooms nearly full of gob.	92 acres mined. Depth, see sections on Plates 14, 16, and 17; thickness, 4 feet 3 inches; rooms nearly full of gob; conditions good; at northwest end of property vein too thin to mine at present.
Dunmore No. 3	do	Pillars sound, of usual size; chambers partly filled; depth, 704 feet.	115 acres mined. Depth, see sections on Plates 14, 16, and 17; thickness, 4 feet 3 inches, includes 1 inch slate and bone top; rooms nearly filled with gob; floor raised for height.

CAPOUSE COLLIERY.

(Works Keyser Valley from Keyser Creek to outcrop and from Jackson Street 1 mile northeastward.)

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
Eight-foot		Eroded	Eroded.
Five-foot		do	Do.
Four-foot		do	Few surface improvements.
Diamond	No. 17	Depth, 92 feet; inaccessible under school on account of removal of surrounding pillars, but under school for area of 200 feet square pillars reported sound and still standing.	262 acres mined. Depth, see sections on Plates 12, 13, and 14; thickness, 10 feet; workings have been remined, and pillars removed over a large area; mining in Diamond bed has ceased.
Rock	do	Depth, 136 feet; inaccessible for reason stated above; similar conditions prevail; nearest accessible point 400 feet from school.	193 acres mined. Depth, see sections on Plates 12, 13, and 14; thickness, 3 feet 10 inches; rooms two-thirds filled with gob; partly remined and inaccessible.
Big	do	Depth, 216 feet; pillars as shown on maps; sound, except slight chipping; local falls in rooms under school.	317 acres mined. Depth, see sections on Plates 12, 13, and 14; thickness, 13 feet 3 inches, includes 9 inches refuse; local falls; no remining as yet; few improvements on surface.
New County	do	Depth, 246 feet; rooms two-thirds filled with gob; also local falls; pillars good; no indication of settlement.	100 acres mined. Depth, see sections on Plates 12, 13, and 14; thickness, 6 feet 8 inches, includes 2 feet 11 inches of refuse; rooms two-thirds filed with gob; numerous local falls in chambers; no indication of present settlement; remining near outcrop.
Clark	do	Depth, 311 feet; water under school prevented approach nearer than 150 feet; pillars sound, except some chipping; rooms wide; pillars usual size, well distributed; conditions fair.	412 acres mined. Depth, see sections on Plates 12, 13, and 14; thickness, 8 feet, includes 11 inches refuse; many local falls, but no squeeze or other settlement; good roof; fair conditions at present; no remining except at outcrop.

Dunmore No. 1	do	Depth, 360 feet; not mined	This vein not mined as yet; too thin. Depth, see sections on Plates 12, 13, and 14.
Dunmore No. 2	do	Depth, 380 feet; pillars sound, usual size; rooms nearly filled with gob; conditions good.	139 acres mined. Depth, see sections on Plates 12, 13, and 14; thickness, 3 feet 2 inches, includes 6 inches refuse; bottom raised for height; no falls; rooms filled with gob, except roadway; conditions good.
Dunmore No. 3	do	Depth, 480 feet; not mined	55 acres mined. This vein not being mined; too thin for profitable mining at present.

WEST RIDGE COLLIERY.

(Works Providence section, North Main Avenue to outcrop between Putnam and Clearview Streets.)

Eight-foot		Eroded	Eroded.
Five-foot	No. 40	Depth, 66 feet; workings inaccessible; approached to point about 300 feet from school; workings filled with falling fire-clay roof; workings now controlled by Clearview Coal Co.	84 acres mined. Depth, see sections on Plates 2, 7, 11, and 13; thickness, 4 feet clear; roof falling; 3½ to 4 feet of fire clay and bone that fall soon after mining and fill the chambers; driving chambers stowed with rock from next vein below. Much of the surface is unimproved.
Top split of Four-foot.	do	Depth, 88 feet (see Clearview Coal Co., p. 43)	9 acres mined as separate bed. Depth, see sections on Plates 2, 7, 11, and 13; thickness, 18 to 30 inches; 3 to 4 feet of rock raised for height; all available space filled with rock and the surplus stowed in Four-foot and Five-foot beds.
Four-foot	do	Depth, 118 feet. Reported formerly worked by West Ridge, but this part now controlled by Clearview Coal Co. (see p. 43).	90 acres mined. Depth, see sections on Plates 2, 7, 11, and 13; thickness, 3 feet clear coal; falling rock roof; workings filled with falling roof and rock from top split.
Diamond, Rock, Big, New County, Clark.	do	These beds worked by Von Storch colliery and Delaware & Hudson Co. (see p. 35).	See page 35.
Dunmore No. 1	do	Depth, 564 feet; extensions of working here since Stevenson and Knight report; pillars sound and chambers well filled, except roadways.	36 acres mined. Depth, see sections on Plates 2, 7, 11, and 13; thickness, 3 feet 1 inch, 4 inches of refuse; 3 feet of bottom raised for height; rooms filled with gob, except roads; pillars sound; conditions apparently good.
Dunmore No. 2	do	Depth, 616 feet; workings now extended under this school; pillars sound and usual size; rooms filled with gob, except roadway; conditions good.	43 acres mined. Depth, see sections on Plates 2, 7, 11, and 13; thickness, 2 feet 8 inches, 3 inches of refuse; 4 feet of bottom taken up for height; rooms, except roadway in center, filled with gob.
Dunmore No. 3	do	Depth, 686 feet; mined under school, but inaccessible on account of gas and water; conditions reported unchanged since Stevenson and Knight report.	99 acres mined. Depth, see sections on Plates 2, 7, 11, and 13; thickness, 3 feet 9 inches, including 7 inches of refuse; at west end of property this bed is too thin to mine as yet; 2 to 3 feet of bottom raised for height; rooms nearly full of rock, except roadway; first mining completed and abandoned.

Scranton Coal Co. collieries—Continued.

RICHMOND NO. 3 COLLIERY—BRYDEN SHAFT.

(Works center of valley. Area bounded by river, Olyphant Road, and Manville farm and narrow strip extending to East Market Street.)

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
Eight-foot	No. 39	Eroded	Eroded.
Five-foot	do	do	Do.
Four-foot	do	do	Do.
Diamond	do	do	Do.
Rock	do	Depth, 138 feet; not mined	Not mined; depth, 109 feet under river flats; much sand and gravel, with thin rock cover over bed; too dangerous to mine.
Big	do	Depth, 200 feet; pillars large and firm; present conditions good	86 acres mined. Depth, see sections on Plate 9; thickness, 13 feet 1 inch; 2 feet 7 inches refuse; top bench not removed on first mining; now being mined; conditions fair; under river flat considerable depth of gravel and sand above the rock.
New County	do	Not mined	Depth, see sections on Plate 9; not mined; too thin or dirty to be profitably mined at present.
Clark	do	Depth, 366 feet; pillars usual size and sound except air chipping; roof good; no indication of settlement.	95 acres mined. Depth, see section on Plate 9; thickness, 5 feet 9 inches, including 4 inches refuse; pillars look fair, but all show chipping, probably air-slacked.
Dunmore No. 1	do	Thin and unworkable at present	Thin and not mined. At Dickson and Manville this bed is split; the upper part is known as the Dunmore No. 1 and the lower split is called the Dunmore No. 2.
Dunmore No. 2	do	Depth, 520 feet; pillars sound and as shown on maps; rooms walled with gob on both sides of road; conditions good.	76 acres mined. Depth, see section on Plate 9; thickness, 4 feet 6 inches, includes 1 foot bone on top; 1½ feet of bottom rock taken up for height, and chambers nearly full of gob, except center roadway. This bed is known as the No. 3 at Dickson.
Dunmore No. 3	do	Depth, 554 feet; pillars usual size, sound and firm; rooms well filled with gob, except roadway in center; conditions good.	86 acres mined. Depth, see sections on Plate 9; thickness, 4 feet 3 inches, includes 1 foot 1 inch refuse on top; 1½ feet of bottom raised for height; rooms, except roadway, filled with gob. At Dickson and Manville this bed is known as the No. 4, or China bed.

Delaware, Lackawanna & Western Coal Co. collieries.

NATIONAL COLLIERY.

(Works South Scranton section, from Beech Street to city line, and from river to outcrop.)

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
Eight-foot		Eroded	Eroded.
Five-foot		do	Do.
Four-foot		do	Do.
Diamond		do	Do.
Rock		do	Do.
Big and New County.	No. 7	Big bed eroded under all school property; about over outcrop of New County vein.	73 acres mined. Depth, see section on Plate 20; thickness of Big vein, 12 to 14 feet; of New County, 5 feet; close together and near surface; long since mined and caved; now reopening to reclaim the pillars.
Clark	do	Depth, 72 feet; nearest chamber, 60 feet from lot; now working toward school; not mined under school at present; this bed eroded under the other school properties on the south side.	176 acres mined. Depth, see section on Plate 20; thickness, 4 feet 7 inches, includes 11 inches of refuse; openings large and pillars small and chipping in old workings; in recent workings nearer out crop chambers 25 feet and pillars 26 feet; chambers one-half filled with gob; roadway on side about 10 feet wide; pillars sound.
Dunmore No. 1		Not mined; too thin	This bed here too thin to mine.
Dunmore No. 2	No. 7	Depth, 195 feet; approached to within 40 feet of school; too dangerous to go under school; pillars small and weak, partly crushed; indicate incipient squeeze.	752 acres mined. Depth, see sections on Plates 19, 20, and 21; thickness, 8 feet 6 inches with top bench mined; 2 feet 7 inches contains about 1 foot 4 inches of coal.
	No. 11	Depth, 157 feet; workings open; pillars small but sound; openings large; roof good.	These are mainly very old workings which have been partly remined since old maps were made, hence pillars are not as shown on map. Pillars average small; openings large. In many places pillars are chipped and cracked from pressure. Mines now being resurveyed. No mining under city in this bed at present.
	No. 10	Depth, 96 feet; pillars very small; openings large; gob piers built; roof strong; no caving.	
	No. 8	Depth, 170 feet; mined but inaccessible on account of being filled with water.	
	No. 15	Depth below cellar of school, 11 feet; shaft in school yard, through sandstone; coal pillars small, openings large; 12 sandstone and cement piers 9 feet square; conditions at present good.	
Dunmore No. 3		Thin, and not mined	This bed very thin; not mined.

Delaware, Lackawanna & Western Coal Co. collieries—Continued.

DODGE COLLIERY.

(Workings mainly in Taylor Borough. Now opening upper veins in Twenty-second ward of city.)

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
Eight-foot	No. 43	Eroded	Mainly eroded; may perhaps be present under very small area under highest land.
Five-foot	do	Depth, about 25 feet; not yet mined; preparations to mine now in progress.	Not yet mined; thickness, 2 to 3 feet.
Top split of four-foot	do	Depth, 49 feet; not yet mined; new workings now about 150 feet from the school; chambers will soon extend under school.	Mines now being opened; depth, see sections on plate 18; thickness, $2\frac{1}{2}$ feet; $4\frac{1}{2}$ feet of bottom raised for height.
Underlying veins	do	All underlying beds worked from Bellevue colliery (see p. 27)	Dodge colliery does not operate lower beds under this city.

HAMPTON COLLIERY.

(Works Diamond and Rock veins only. Hyde Park and Keyser Valley, west of South Main and south of Luzerne Streets.)

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
Eight-foot		Eroded	Eroded.
Five-foot, four-foot.	No. 32 Annex	See Hyde Park colliery, page 29	Not mined as yet (see Hyde Park colliery, p. 29).
Diamond	do	Depth, 320 feet; worked, and abandoned for a long time, but now remining for bottom coal; pillars reported sound, being reinforced by gob walls from the remining.	561 acres mined. Depth, see sections on Plates 14 to 16; thickness, about 10 to 12 feet; top bench, 6 to 8 feet, formerly mined; now remining for bottom bench, and reinforcing pillars with gob walls; much of mined area long closed by old squeeze.
	No. 31	Depth, 258 feet; caved and inaccessible.	
	No. 19	Depth, 291 feet; caved and inaccessible.	
Rock	No. 22 Annex	Reported inaccessible on account of caves; maps show fair pillar support.	570 acres mined. Depth, see sections on Plates 14 to 16; thickness, $9\frac{1}{2}$ feet, includes 3 feet of refuse; long worked and mostly abandoned; bed squeezed and closed in places; now reclaiming pillars under Keyser Valley.
	No. 19	Depth, 325 feet; caved and inaccessible.	
	No. 31	Depth, 286 feet; caved and inaccessible.	
Big and other lower beds.	No. 32 Annex	Mined at Central and Hyde Park collieries (see pp. 28, 29)	These beds mined by Central and Hyde Park collieries (see pp. 28, 29).

BELLEVUE COLLIERY.

(Works Hyde Park and Bellevue sections from river to South Main Avenue, between Dodge and Oxford mines.)

Eight-foot		Eroded	Eroded.
Five-foot, four-foot		See Dodge colliery, page 26	See Dodge colliery, page 26.
Diamond	No. 12	Depth 13 to 40 feet; dip about 10° NW.; west two-thirds of building on solid pillar; east one-third over workings; large openings and small pillars; now remining for bottom coal; should be properly filled.	234 acres mined. Depth, see sections on Plates 15 and 17; thickness, top bench 6 to 8 feet, with 1½ feet refuse; bottom bench 3 to 6 feet, about one-half refuse; top bench mined years ago and abandoned; now remining the whole area for bottom bench; pillars generally small, but sound; are now reinforced by gob walls as part of the process of remining for bottom bench. The roof in this locality is relatively strong, and in this respect quite different from Providence section.[a]
	No. 13	Depth, 230 feet; inaccessible because crushed	
	No. 29	Eroded	
	No. 32	Depth, 185 feet; on roll; solid under school; conditions good at present.	
	No. 43	Depth, 221 feet; pillars small but sound; now remining for bottom coal and stowing rock and reinforcing pillars with gob walls.	
Rock	No. 13	Depth, 232 feet; approached to about 100 feet from this school; inaccessible farther on account of squeeze.	371 acres mined. Depth, see sections on Plates 15, 17; thickness, 8 feet 9 inches; 3 inches refuse. This vein entirely closed and inaccessible on account of squeeze. Reported to have forced Rock vein pillars down into openings in Big vein, and also affected portions of Diamond bed.[a]
	Nos. 12, 29, 32, 43	Inaccessible on account of old crush	
Big	No. 12	Depth about 145 feet; workings abandoned; openings large; pillars sound; many local falls of top coal in chambers; large pillars under school; could be easily flushed from bore hole.	367 acres mined. Depth, see sections on Plates 15 and 17; thickness, about 18 feet. First mining in either top or bottom bench; then remined in places for remaining bench. This bed closed and inaccessible in many parts of mine, due to breaking down of roof.[a]
	No. 13	Depth, 348 feet; only top bench mined under school, and seam not squeezed here; pillars small for such a thick bed.	
	No. 29	Depth, 131 feet; thickness, 13 feet; bottom bench worked; local falls of top coal and rock under corner of school, but major part of building on large block of solid coal.	
	No. 32	Depth, 325 feet; caved and inaccessible.	
	No. 43	Not mined; access under some of above schools difficult.	
New County	No. 12	Depth, 160 feet; recently mined; endeavoring to columnize pillars	118 acres mined. Depth, see sections on Plates 15 and 17; thickness, about 7 to 8 feet; only about 10 feet below Big vein; pillars generally sound, but not columnized under Big vein; columnization attempted in recent mining.
	No. 13	Depth, about 360 feet; inaccessible on account falls	
	No. 43	Depth, 380 feet; worked from Bellevue; pillars usual size as per maps	
	Nos. 32 and 29	Not mined at present.	

[a] Surface subsidence may and often does occur where pillars are strong, and without much warning or crushing of pillars, if conditions exist such as those under Hyde Park, where many thick beds lie close together and the pillars in the several beds are not columnized, thus permitting pillars of an upper bed to break through the strata into the chambers or openings of an underlying bed.

Delaware, Lackawanna & Western Coal Co. collieries—Continued.

BELLEVUE COLLIERY—Continued.

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
Clark	No. 12	Depth, about 240 feet; nearly solid now; mined under north wall of school; conditions good.	335 acres mined. Depth, see sections on Plates 15 and 17; thickness 7 to 13 feet, with 1 to 2 feet of refuse; first mining in bottom bench; now remining for top bench, in places; pillars generally standing and well distributed; old squeezed portions east of school No. 32, but gangways reopened;[a] conditions generally fair.
	No. 13	Depth, about 400 feet; roof good; no falls; pillars sound and as represented by maps; conditions fair.	
	No. 29	Depth, about 207 feet; approached to 250 feet of school and stopped by local falls; workings reported good condition; rooms, 25 feet; pillars, 25 feet.	
	No. 32	Depth, 475 feet; stands on large pillar under whole lot near crest of roll; conditions good.	
	No. 43	Depth, 430 feet; pillars standing; local falls; conditions fair.	
Dunmore No. 1		Not mined	3 acres mined. Preparations now being made to work this bed.
Dunmore No. 2	No. 12	Depth, 350 feet; mined; condition good	84 acres mined. Depth, see sections on Plates 15 and 17; thickness 5 to 6 feet; pillars usual size, and strong; conditions good throughout.
	No. 43	Not mined	
	No. 13	Depth, about 510 feet; gangway under school; conditions good	
	No. 29	Depth, 320 feet; workings in good condition; pillars sound and usual size.	
	No. 32	Depth, 600 feet; conditions good	
Dunmore No. 3		Not mined	38 acres mined. Opening in preparation for working this bed.

CENTRAL COLLIERY.

(Works Hyde Park section, South Main Avenue and Keyser Valley, south of Washburn Street.)

Eight-foot		Eroded	Eroded.
Five-foot		Part eroded	Partly erod d.
Four-foot		Part not mined	Balance not mined.
Diamond Rock		Worked from Hampton colliery (see page 26)	See page 26.
Big	No. 32 Annex	Reported caved and inaccessible	362 acres mined. Depth, see sections on Plates 14, 15, and 16; thickness, 13 to 18 feet; 2 to 3 feet refuse; this vein is generally closed by numerous local falls; pillars doubtless crushed or shattered in some places.[a]
New County	do	Reported flushed and inaccessible	300 acres mined. Depth, see sections on Plates 14, 15, and 16; thickness, 9 to 10 feet; 2 feet refuse.[a]

Clark	do	Pillars sound, as shown on map; some local falls	370 acres mined. Depth, see sections on Plates 14, 15, and 16; thickness, 8 feet; 1 foot refuse.
Dunmore No. 1	do	Pillars sound; roof good; hard floor; recently mined; conditions good.	10 acres mined. Depth, see sections on Plates 14, 15, and 16; thickness 4 feet 11 inches coal and 3 feet 1 inch refuse; twin bed—perhaps represents Dunmore Nos. 1 and 2 united.
Dunmore Nos. 2 and 3.		Not mined	Not mined.

HYDE PARK COLLIERY AND CONTINENTAL COLLIERY.

(Work Keyser Valley and Hyde Park section to South Main Avenue, between Lafayette Street and Luzerne Street.)

Eight-foot		Eroded	Eroded.
Five-foot	No. 31	Depth, 104 feet; mine just being opened; gangway working toward school, but under school not yet mined; conditions good.	2 acres mined. Depth, see sections on Plates 14 and 16; thickness, 4 feet 8 inches clean coal. This bed extends under Hyde Park section generally, but until recently no mining has been done in it; now being developed from Hyde Park colliery.
	No. 19	Depth, about 140 feet; not yet mined	
Four-foot	No. 31	Depth, about 144 feet; mine just being opened; gangway extending quite close to, but not now under the school; conditions good.	10 acres mined. Depth, see sections on Plates 14 and 16; thickness, 2 feet 10 inches, including 1 inch refuse. This bed extends under the Hyde Park section generally, but until recently has not been mined; now being developed from Hyde Park colliery.
	No. 19	Depth, about 175 feet; not mined	
Diamond	No. 31	Mined from Hampton (see p. 26)	355 acres mined. (See p. 26.)
Rock		Mined from Hampton (see p. 26)	240 acres mined. (See p. 26.)
Big	No. 31 No. 19	Depth, 374 feet; worked and caved; inaccessible. Depth, 405 feet; inaccessible; mined and caved	514 acres mined. Depth, see sections on Plates 14 and 16; thickness, 13 to 18 feet; long mined; caved over large area and workings now abandoned.[a]
New County	No. 31	Depth 423 feet; pillars, regular and sound; no indications of settlement; old workings; good roof.	431 acres mined. Depth, see sections on Plates 14 to 16; thickness, 8 to 10 feet, includes 2 feet of refuse; workings in this bed look fair; workings accessible and pillars standing over large areas; no general squeeze; the caves or squeezes are local. Pillars in this and overlying beds are not columnized.[a]
	No. 19	Depth, 440 feet; half of building on solid coal; remainder part mined; pillars fair size; roof and floor good.	
	No. 14	Depth, 397 feet; mine openings filled with gob because of squeeze in progress in 1908; approached on gangway to 50 feet from school lot; all quiet now.	

[a] Surface subsidence may and often does occur where pillars are strong, and without much warning or crushing of pillars, if conditions exist such as those under Hyde Park, where many thick seams lie close together and the pillars in the several beds are not columnized; pillars of an upper bed are thus permitted to break through the intervening strata into the chambers or openings of an underlying bed.

Delaware, Lackawanna & Western Coal Co. collieries—Continued.

HYDE PARK COLLIERY AND CONTINENTAL COLLIERY—Continued.

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
Clark	No. 31	Depth, 483 feet; roof, floor, pillars good; gangway, containing flush pipe, under part of lot; chambers under school flushed.	569 acres mined. Depth, see sections on Plates 14 and 16; thickness, 8 feet 8 inches, includes 2 feet refuse; pillars standing and workings in fair condition on major part of this section; now remining in some parts for bottom coal; this causes some chipping of pillars; some local falls and local squeezes.
	No. 19	Depth, about 495 feet; located over basin filled with water; not accessible.	
Dunmore Nos. 1 and 2.	No. 31	Depth, about 529 feet; now opening these beds; not now mined under school, but gangway is approaching; pillars, roof, and floor all good.	8 acres mined. Depth, see sections on Plates 14 and 16; thickness, No. 1 bed, 1½ to 2 feet; dividing rock, 8 feet; No. 2 bed, 3½ feet. Mining under this section in these beds was recently begun and is now developing.
	No. 19	Not mined	
Dunmore No. 3		Not mined in this section	Not mined in this section.

DIAMOND COLLIERY.

(Works North Hyde Park to Providence; river to Keyser Creek, between Pettebone Street and Court Street.)

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
Eight-foot		Eroded under schools	54 acres mined. Depth, see sections on Plate 12; thickness, 8 feet 8 inches, includes 1½-foot refuse. This bed present only under highest part of Hyde Park Hill and Brisbin; has been mined; reclaiming pillars now causing surface subsidence.
Five-foot	No. 20	Depth, 51 feet; mined by Diamond drift	200 acres mined. Depth, see sections on Plate 12; thickness, 5 feet. This has been well mined over from Diamond drift; partly caved and abandoned.
	No. 41	Depth, 60 feet; mined, caved, and inaccessible under both schools	
Four-foot	No. 20	Depth, 89 feet; on solid coal dividing Diamond drift workings and Brisbin workings; over a fault; surrounding pillars fair; fair roof.	42 acres mined. Depth, see sections on Plate 12; thickness, Twin bed 7 to 8 feet, including dividing rock 2½ feet thick; this bed nearly closed, result of Diamond squeeze.
	No. 41	Depth, 115 feet; disturbed by squeeze two years ago; now closed and inaccessible; approached to within about 60 feet of school.	
Diamond	No. 20	Depth, 255 feet; mined, closed, and inaccessible	630 acres mined. Depth, see sections on Plate 12; thickness, 8 to 12 feet; mined from Diamond shaft; closed by falling roof and general squeeze; [a] now inaccessible.
	No. 21	Eroded	
	No. 41	Depth, 242 feet; closed, caved, and inaccessible.	
Rock	No. 20	Depth, 284 feet	483 acres mined. Depth, see sections on Plate 12; thickness, 8 feet; mined from Diamond shaft; closed by general squeeze; now mining top split in Tripp shaft; hindered by 8 to 15 feet rock. [a]
	No. 41	Depth, 272 feet; caved and inaccessible under both schools	
	No. 21	On outcrop; not mined; too close to surface	

Big	No. 21	Depth, 107 feet; map shows large pillar under school, but mine workings caved and inaccessible.	499 acres mined. Depth, see sections on Plate 12; thickness, 10 to 13 feet; mined from Diamond shaft; closed by general squeeze.[a]
	No. 20	Depth, 345 feet; caved and inaccessible	
	No. 41	Depth, 331 feet; caved and inaccessible	
New County	No. 20	Depth, 400 feet; not mined; nearest work 450 feet distant	131 acres mined. Depth, see sections on Plate 12; thickness, 5½ feet, includes 1½ feet of refuse; this vein open and working from Diamond shaft; room, 20 feet wide, 50 feet between centers; gob walls both sides of rooms; to dip from school No. 41 the workings are caved and inaccessible.[a]
	No. 2	Depth, 160 feet; not mined	
	No. 41	Depth, 388 feet; we reached point in workings near school; chambers now being worked toward school; rooms, 26 feet; gob walls both sides.	
Clark	No. 20	Depth, 462 feet	615 acres mined. Depth, see sections on Plate 12; thickness, 7½ feet, includes 8 inches refuse; largely mined over; disturbed by the general squeeze, and now full of water.
	No. 41	Depth, 440 feet; inaccessible under both schools, on account squeezed area and water.	
	No. 21	See Manville colliery, page 32	
Dunmore Nos. 1, 2, and 3.		These seams not now mined under any school building	21 acres mined. Depth, see sections on Plate 12. These beds are 2 to 5 feet thick and are only being mined from Tripp shaft, but workings are of small extent.

BRISBIN COLLIERY.

(Works under Keyser Valley and Hill section, between Hyde Park and Providence.)

Eight-foot		No schools over Brisbin workings	24 acres mined. Depth, see sections on Plate 7; thickness, 8 feet 10 inches; mined out and robbed.
Five-foot		do	130 acres mined. Depth, see sections on Plate 7; thickness, 8 feet 10 inches.
Four-foot		do	123 acres mined. Depth, see sections on Plate 7; thickness 3 feet.
Diamond		do	Worked from Diamond colliery. (See p. 30.)
Rock		do	182 acres mined. Depth, see sections on Plate 7; thickness, 3 feet 11 inches; mined out and caved.
Big		do	289 acres mined. Depth, see sections on Plate 7; thickness, 10 feet 2 inches; caved and closed.
New County		do	00 acres mined. Too thin to mine, except on mountain side.
Clark		do	404 acres mined. Depth, see sections on Plate 7; thickness, 7 feet 7 inches; caved and closed.
Dunmore Nos. 1, 2, and 3.		do	4 acres mined. Now beginning to be opened.

[a] Surface subsidence may and often does occur where pillars are strong, and without much warning or crushing of pillars, if conditions exist as those under Hyde Park, where many thick seams lie close together and the pillars in the several beds are not columnized; pillars of an upper bed are thus permitted to break through the intervening strata into the chambers or openings of an underlying bed.

Delaware, Lackawanna & Western Coal Co. collieries—Continued.

CAYUGA COLLIERY AND STORRS COLLIERY.

(Work section between Keyser Valley and Leggetts Creek, from Bloom Avenue to foot of West Mountain.)

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
Eight-foot		Eroded	Eroded.
Five-foot	No. 22	Depth, 36 feet; solid block coal under school	268 acres mined. Depth, see sections on Plates 11 and 13; thickness, 4 feet 8 inches, includes 8 inches of refuse; pillars now being removed; space stowed with gob and surplus rock from a lower bed.
Four-foot	do	Depth, about 124 feet; mined, but inaccessible on account of danger due to falling roof.	168 acres mined. Depth, see sections on Plates 11 and 13; thickness, 4 feet, includes 8 inches of refuse; falling roof, 2½ feet thick, closes the mine after standing; now mining top split of Four-foot, 20 inches thick, and stowing surplus rock in 5-foot vein.
Diamond	do	Depth, 186 feet; approached to 60 feet from school; pillars sound and of fair size; openings closed by falling roof; roof will not stand after timbers rot; pillars do not crush.	490 acres mined. Depth, see sections on Plates 11 and 13; thickness, 8 feet, includes 8 inches refuse; caved in many places; bad fire-clay roof which falls soon after working stops; pillars strong.[a]
Rock	do	Depth, 280 feet; pillars sound; rooms gobbed on one side; conditions good.	174 acres mined. Depth, see sections on Plates 11 and 13; thickness, 3 feet 3 inches clear; taking down 2½ feet of roof for height; roof good; conditions fair.
Big	do	Depth, 317 feet; caved, closed, and inaccessible	623 acres mined. Depth, see sections on Plates 11 and 13; thickness, 10 feet, 1 foot 3 inches refuse; old mine caved and closed.
New County		Not mined; too thin	Not mined; too thin.
Clark	do	Depth, 476 feet. This section of working flushed to within 2½ feet of roof; flushing still in progress.	576 acres mined. Depth, see sections on Plates 11 and 13; thickness, 8 feet, includes 2 inches refuse; many local falls, but no general squeeze; workings now being flushed with culm.
	No. 23	Depth, 423 feet; mined but not accessible	
Dunmore No. 1		Not mined	Not mined, but now being opened.
Dunmore No. 2		do	Not mined; opening in preparation.
Dunmore No. 3		do	Do.

[a] Surface subsidence may and often does occur where pillars are strong, and without much warning or crushing of pillars, if conditions exist as those under Hyde Park, where many thick beds lie close together and the pillars in the several beds are not columnized; the pillars of an upper bed are thus permitted to break through the strata which separate the seams into the chambers or openings of an underlying bed.

People's Coal Co.

OXFORD COLLIERY.

(Works Hyde Park section, from the river to South Main Avenue, between Lackawanna and Luzerne Streets.)

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
Eight-foot		Eroded	Eroded.
Five-foot, four-foot		Not mined	Not mined at present.
Diamond	No. 14	Depth, 252 feet; approached to point under northwest corner of building; solid pillar under rest of school lot; bed, 10 feet thick; falls in room approaching school; conditions good.	84 acres mined. Depth, see sections on Plate 17; thickness, 10 to 15 feet; original workings in top bench, 3 to 6 feet, with about 2½ feet refuse; over 5 acres caved under No. 16 School; pillars outside of cave apparently sound;[a] no indications of future caving; gob piers built under vicinity of Lackawanna Railroad Co.'s bridge and Lackawanna Avenue.
	No. 16	Depth, 200 feet; caved and inaccessible; approached to edge of coal worked by Bridge Coal Co.	
Rock	No. 14	Depth, 294 feet; inaccessible; worked from Hampton colliery	104 acres mined. Depth, see sections on Plate 17; thickness, 8 feet 2 inches, with 1 inch refuse; over 5 acres caved under No. 16 School; pillars sound surrounding cave, and no indications of spread of cave;[a] parts of Oxford working effectually flushed with culm.
	No. 16	Depth, 229 feet; caved and inaccessible; worked by Bridge Coal Co.	
Big	No. 14	Depth, about 364 feet; inaccessible, caved, and flushed	116 acres mined. Depth, see sections on Plate 17; thickness, 12 to 18 feet, with 2 to 3 feet of refuse; pillars and chambers of usual size; local falls, but no serious chipping or other indications of extension of cave, beyond 1 or 2 acres under Schoo lNo. 16.[a]
	No. 16	Depth, 289 feet; inaccessible on account of cave; pillars surrounding cave appear in fair condition and usual size; a few local falls, but no indications of extension of caving; worked by Bridge Coal Co.	
New County	No. 14	See Hyde Park colliery, page 29	120 acres mined. Depth, see sections on Plate 17; thickness, 7 to 10 feet, with 1 to 2 feet of refuse; partly flushed; pillars standing, strong; roof good; no present indication of squeezing;[a] no caving under No. 16 School.
	No. 16	Depth, about 334 feet; pillars standing in good condition and well distributed; no local falls; no present indication of settlement.	
Clark	No. 14	Depth, 435 feet; approached to within 250 feet of school; now inaccessible account local falls and flushing.	104 acres mined. Depth, see sections on Plate 17; thickness, 7 to 13 feet, about 2 feet refuse; openings large, but pillars firm, with fair distribution; slight chipping, but no present indications of subsidence.
	No. 16	Depth, 370 feet; recently unwatered, and now accessible; pillars standing in good condition except for slight chipping; local falls in chamber under this school; old timber cogs standing, but bearing no weight; mined by Bridge Coal Co.	

[a] Surface subsidence may and often does occur where pillars are strong, and without much warning or crushing of pillars, if conditions exist such as those under Hyde Park, where many thick seams lie close together and the pillars in the several beds are not columnized; pillars of an upper bed are thus permitted to break through the intervening strata into the chambers or openings of an underlying bed.

People's Coal Co.—Continued.

OXFORD COLLIERY—Continued.

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
Dunmore No. 1	No. 14	Depth, 516 feet; mined under northeast and southeast side, but major part solid; chambers well filled with gob, and mining stopped.	21 acres mined. Depth, see sections on Plate 17; thickness, 1 foot of coal, 2 feet of rock, 2½ feet of coal; rock and top bench taken down for height in roads; chambers, 30 feet; pillars, 18 to 20 feet; openings well filled with gob; fairly successful attempt made to columnize the pillars in the Dunmore beds.
	No. 16	Depth, 481 feet; not mined.	
Dunmore No. 2	No. 14	Depth, 567 feet; heading and airway under central and eastern part of building; western part of building over solid coal; recently mined; chambers well filled with gob.	73 acres mined. Depth, see sections on Plate 17; thickness, about 4½ feet, with 6 inches of refuse; roof taken down for roads, and rooms well packed with gob; pillars fairly well columnized.
	No. 16	Depth, 502 feet; not mined under school lot; mined from east side of Chestnut Street westward.	
Dunmore No. 3	No. 14	Depth, 620 feet; gangway and airway under central and eastern part of building; western corner on solid coal; recently mined.	62 acres mined. Depth, see sections on Plate 17; thickness, about 4 feet 10 inches, with 1¾ feet of refuse; recently mined, and pillars fairly well columnized; rooms filled with gob, except in roadways.
	No. 16	Depth, 568 feet; mined from westward only, up to line of school lot; not mined under the lot; mining stopped here.	

Delaware & Hudson Canal Co. collieries.

VON STORCH COLLIERY.

(Works Providence section, river to mountain, between Clearview and Putnam Streets, from river to Cayuga line, between Putnam and William.)

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
Eight-foot		No schools	Worked and robbed.
Five-foot	No. 24 No. 25	Depth, 55 feet; pillars sound; conditions fair. Depth, 37 feet; large pillar under entire school lot.	104 acres mined. Depth, see sections on Plates 7 and 8; thickness, 4 feet 9 inches; 1 inch of refuse; fireclay roof, which falls; pillars well distributed and look good; rooms well packed with gob, inclusive of roadways when finished.
Four-foot	No. 24 No. 40 No. 25	Depth, 147 feet; inaccessible; all openings filled with gob. See West Ridge colliery, page 23. Large pillars under half of school lot; mined under other half; chambers filled; much pressure on pillars from effect of squeezing in Dunmore bed; passageway along east side of Big pillar.	165 acres mined. Depth, see sections on Plates 7 and 8; thickness 3 feet clear; chambers well filled with gob; many parts roadway also filled.
Diamond		Caved; abandoned; inaccessible.	365 acres mined. Depth, see sections on Plates 7 and 8; thickness, 10 to 15 feet, includes 2 to 4 feet refuse. This bed carries 10 to 15 feet of falling fireclay roof which soon disintegrates and falls, filling all openings.
Rock	No. 24 No. 40 No. 25	Depth, 235 feet; solid, and too thin to mine here. Depth, 260 feet; caved and closed. Depth, 216 feet; solid under school lot; mined on west side only at present; vicinity of School No. 25 shows signs of squeeze.	395 acres mined. Depth, see sections on Plates 7 and 8; thickness, 3 feet 6 inches; 2 inches of refuse; falling roof; rooms filled with gob and falling roof.
Big		Caved and closed	397 acres mined. Depth, see sections on Plates 7 and 8; thickness, 11 to 13 feet; closed throughout.
New County		Not mined; to date considered too thin to mine.	6 acres mined.
Clark		Caved and closed	489 acres mined. Depth, see sections on Plates 7 and 8; thickness, 7 to 9 feet; caved and closed throughout.
Dunmore beds		These beds mined by West Ridge colliery (see p. 23). No. 40 School undermined from this colliery in Diamond, Big, and Clark beds, but workings are caved and closed.	

Delaware & Hudson Canal Co. collieries—Continued.

LEGGETTS CREEK COLLIERY.

(Works north Providence section, bounded by East Market Street, North Main Avenue, and the city line.)

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
Eight-foot		Eroded	Eroded.
Five-foot	No. 44	Worked out and abandoned	33 acres mined. Depth, see sections on Plates 10 and 11; thickness, 3 feet 6 inches to 5 feet; worked out and abandoned.
	No. 26	Eroded.	
Four-foot	No. 26	Depth, 66 feet; inaccessible; filled with rock or gangway fallen	263 acres mined. Depth, see sections on Plates 10 and 11; thickness, 3 feet 6 inches; chambers well filled with gob.
	No. 44	Accessible; pillars sound; conditions fair.	
Diamond	No. 24	Depth, 212 feet; caved, closed, and abandoned	263 acres mined. Depth, see sections on Plates 10 and 11; thickness, 8 feet to 10 feet; carries 10 to 15 feet of falling roof of fireclay and shale which has fallen and closed all openings throughout.
	No. 26	Depth, 135 feet; caved, closed and abandoned.	
	No. 44	Caved, closed, and abandoned.	
Rock	No. 24	Depth, 235 feet; not yet mined	98 acres mined. Depth, see sections on Plates 10 and 11; thickness, 2½ to 3 feet; rooms well filled with gob on both sides; conditions fair.
	No. 26	Depth, 172 feet; rooms filled with gob both sides of roadway; pillars sound; roof strong.	
	No. 44	Now extended under school; cob walls both sides; no signs at present of squeeze in Dunmore bed; conditions fair.	
Big		This bed flushed under School No. 26 and caved and closed under Nos. 24, 25, and 44; west half of School No. 25 is over solid pillar in all veins.	375 acres mined. Depth, see sections on Plates 10 and 11; thickness, 11 to 12 feet; mined and abandoned long ago; now caved and closed.
New County		Too thin to mine	Not mined; too thin.
		This bed reported closed under all schools	296 acres mined. Depth, see sections on Plates 10 and 11; thickness, 8 feet; mined, abandoned, and closed.
	No. 26	See Dickson colliery, page 38.	
Dunmore No. 1		Not mined; too thin	Not mined; too thin. Bottom split of Dunmore No. 1 is here known as Dunmore No. 2.
Dunmore No. 2	No. 26	Depth, 531 feet; very thin; not worked	51 acres mined. Depth, see sections on Plates 10 and 11; thickness, 1 to 2½ feet; only small area mined where thickest. This bed at this colliery is known as No. 3.
	No. 44	2½ feet thick; rooms filled with gob.	
Dunmore No. 3 (here known as No. 4).	No. 24	Depth, 670 feet; pillars sound; roof sound; rooms stowed with rock; conditions fair.	333 acres mined. Depth, see sections on Plates 10 and 11; thickness, 4½ feet, with about 1 foot of refuse on top; rooms fair, all gobbed with rock; pillars not sufficiently large or strong to sustain pressure of roof, consequently squeezing is in progress; roof hard and strong, which remains intact after squeeze. This bed is here known as No. 4 Dunmore.
	No. 25	Depth about 653 feet; solid pillar under west half of school; this pillar now affected more or less by a squeeze approaching from the eastward in this bed.	
	No. 26	Depth 573 feet; no signs of squeeze here at present; flush pipe laid from Von Storch breaker to flush this locality, which, judging from experience, is liable to squeeze.	
	No. 44	Closed by squeeze and inaccessible.	

MARVINE COLLIERY.

(Works between Providence and the city line, from Florida Street to Dunmore and Olyphant Road.)

Eight-foot		Eroded	Eroded.
Five-foot	No. 44	Near surface; worked out and abandoned years ago	150 acres mined. Depth, see sections on Plates 9 and 10; thickness, 5 to 8 feet, includes 2 to 3 feet of refuse; bottom bench, 5 feet thick, mined only; this bed mined from Richmond drifts; abandoned and inaccessible.
Four-foot		Operated from Leggetts Creek colliery (see p. 36)	See page 36.
Diamond	No. 44	See Leggetts Creek colliery, page 36	135 acres mined. Depth, see sections on Plates 8 and 10; thickness, 9 to 10 feet; bad falling fireclay roof; now being mined under Marvine farm on east side of mine; on west side now reopening caved area caused by recent general squeeze.
Rock	do	See Leggetts Creek colliery, page 36	This vein not mined at Marvine colliery.
Big	do	Mined, abandoned, and caved	445 acres mined. Depth, see sections on Plates 9 and 10; thickness, 13 to 14 feet; divides into two splits on east side, where it is now being worked under Marvine farm where there are few surface improvements.
New County		Not mined; too thin	Too thin to mine.
Clark	No. 44	Worked from Leggetts Creek colliery (see p. 36)	242 acres mined. Depth, see sections on Plates 9 and 10; thickness, 5 to 6 feet; largely caved and closed on west side; open and partly mined on east side; few improvements on surface east side.
Dunmore No. 1	do	See Leggetts Creek colliery, page 36	Too thin to mine.
Dunmore No. 2			53 acres mined. Depth, see sections on Plates 9 and 10; thickness, $2\frac{1}{2}$ to 3 feet; not much mined as yet.
Dunmore No. 3		No schools over the Marvine workings	74 acres mined. Depth, see sections on Plates 9 and 10; thickness, $4\frac{1}{2}$ feet, includes 1 foot of refuse. These workings have suffered by general squeeze on west side at Marvine; squeeze has more or less affected overlying beds and has extended to Leggetts Creek mine; now working under good conditions on east side under Marvine farm.

Delaware & Hudson Canal Co. collieries—Continued.

DICKSON COLLIERY.

(Works Green Ridge section from the river to the Dunmore line and from Delaware Street to Columbia Avenue.)

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
All beds above Big		Eroded	Eroded.
Big	No. 27	Just over the line on Pennsylvania Coal Co. land and not undermined.	101 acres mined. Depth, see sections on Plates 6 and 8; thickness 12 feet; includes 2 feet 4 inches of refuse; workings stopped account thin cover of sand and gravel; standing pillars fair.
New County		Contains too much refuse to mine at present. About 5 feet thick.	
Clark	No. 27	Depth, 226 feet; this school on Pennsylvania Coal Co. land, near land line; not mined; roll passes under school.	194 acres mined. Depth, see sections on Plates 6 to 8; thickness of 8 feet includes 9 inches of refuse; pillars standing in fair condition; local falls, but no squeeze as yet.
Dunmore No. 1	do	Depth, 289 feet; near to land line on Pennsylvania Coal Co. land; not mined.	83 acres mined. Depth, see sections on Plates 6 and 8; thickness, 2 feet 2 inches; well mined over; rooms well gobbed; pillars sound; conditions fair. This is bottom split of the bed and is here known as Dunmore No. 2, top split being called No. 1.
Dunmore No. 2	do	Just over line on Pennsylvania Coal Co. land; not mined.	50 acres mined. Depth, see sections on Plates 6 and 8; bed rather thin, and therefore not extensively mined; where mined, rooms filled and conditions fair; here known as Dunmore No. 3.
Dunmore No. 3	do	Depth, 384 feet; just over line on Pennsylvania Coal Co. land; not mined.	351 acres mined. Depth, see sections on Plates 6 and 8; thickness, 3 to 3½ feet; well mined over; pillars generally sound; rooms well filled with gob; conditions fair.

Manville colliery—Operated jointly by the Delaware, Lackawanna & Western and Delaware & Hudson Companies.

(Works Green Ridge section, from the river to the Dunmore line, between Larch and Delaware Streets.)

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
All beds above the Big vein.		Eroded	Eroded.
Big	No. 21	Worked by Diamond colliery. (See p. 31)	Eroded, except small area on west side of river; worked by Diamond colliery and now caved.
	Nos. 28 and 34	Eroded	
New County	No. 21	Depth, about 160 feet; not mined; workings not extended under school.	16 acres mined. Depth, see sections on Plates 5 and 6; thickness, 5 feet 9 inches; includes 2 feet of refuse; twin bed carries top split 3 to 4 feet thick; separated from main bottom split by 8 to 10 feet of rock; mining only recently begun; chambers, 24 feet; pillars, 36 feet.
	No. 28	Depth, about 100 feet.	
	No. 34	Depth, about 170 feet; not mined.	
Clark	No. 21	Depth, about 261 feet; inaccessible on account of water	315 acres mined. Depth, see sections on Plates 5 and 6; thickness 7 feet, with 6 inches of refuse; old workings; rooms large; pillars well distributed over greater part; considerable chipping of pillars in localities throughout mine; chipping apparently caused more from weight than from air slacking; the southern section of the mine is now caved and closed.
	No. 34	Depth, about 220 feet.	
	No. 28	Depth, 180 feet; workings accessible; openings large; pillars chipped considerably, more on account of weight than air slacking.	
Top Split (here known as Dunmore No. 1).		Not mined	Not mined.
Dunmore No. 1 (here known as No. 2).	No. 21	Depth, about 325 feet; pillars sound and as shown; rooms filled with gob, except roadway.	215 acres mined. Depth, see sections on Plates 5 and 6; thickness, 3½ feet, includes 6 inches of refuse; rooms well gobbed outside of center roadway; conditions fair; no signs of subsidence. The beds known at Manville as No. 1 and 2 Dunmore are really No. 1 Dunmore as known elsewhere, divided into two splits. (See Green Ridge colliery, p. 41.)
	No. 34	Depth, 267 feet; pillars sound and as represented; rooms filled with gob, except roadway.	
Dunmore No. 2 (here known as No. 3).	No. 21	Depth, about 365 feet; pillars sound and well distributed; rooms full of gob, except roadway in center; openings large; conditions fair.	330 acres mined. Depth, see sections on Plates 5 and 6; thickness, 3 feet 3 inches coal; raise 3 to 4 feet of bottom for height; rooms packed with gob, leaving 10 to 12 feet of roadway in center; pillars well distributed, but undersize; no signs of squeeze noted, but squeezed area reported near School No. 28. This bed is elsewhere known as Dunmore No. 2.
	No. 34	Depth, 387 feet; pillars sound and rooms full of gob, except roadway in center.	
	No. 28	Depth, 285 feet; workings inaccessible; reported filled and settled.	
Dunmore No. 3 (here known as No. 4).	No. 21	Depth, 447 feet; pillars sound and according to maps; rooms filled with gob, except roadway; conditions fair.	311 acres mined. Depth, see sections on Plates 5 and 6; thickness 3 feet 8 inches, with 1 inch of refuse; 3 to 4 feet bottom rock lifted and stowed in chambers both sides of 10 or 12 foot roadway; pillars well distributed and sound, but rather small; no weakness noted or reported. This bed is known elsewhere as Dunmore No. 3.
	No. 34	Depth, 376 feet; pillars sound and as represented; rooms filled with gob, excepting roadway; conditions fair.	
	No. 28	Depth, about 345 feet; pillars sound and as shown on maps; rooms filled with gob, except roadway; conditions fair.	

Pennsylvania Coal Co. colliery.

NO. 2 SHAFT COLLIERY.

(Works Petersburg section, between Myrtle Street and Dunmore, east of Taylor Avenue.)

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
Beds above the Clark.		All eroded	1 acre mined. All beds above the Clark are eroded.
Clark	No. 5	Depth, 30 feet; pillars standing firm and sound; no falls; good roof.	20 acres mined. Depth, see sections on Plates 4 and 24; thickness, 5 feet; 1 foot bottom lifted in roads; chambers one-sixth full of gob; old mine; pillars strong; company now reopening, preparing to flush with culm and reclaim pillars.
Dunmore No. 1	do	Depth, 170 feet; pillars strong and well distributed; no signs of weakness; good roof.	105 acres mined. Depth, see sections on Plates 4 and 24; thickness, 4 feet 10 inches clear coal; pillars sound, well distributed, and strong; no signs of weakness; top bench 3½ feet thick, 3 feet above bed; company now remining near outcrop for top coal.
Dunmore No. 2	do	Depth, 200 feet; pillars strong; roof excellent; condition good	73 acres mined. Depth, see sections on Plates 4 and 24; thickness, 5 feet 7 inches; 3 inches of refuse; pillars strong and well distributed; no signs of weakness; pillars near outcrop being reclaimed.
Dunmore No. 3	do	Depth, 250 feet; not mined	16 acres mined. Depth, see sections on Plates 4 and 24; thickness about 3 to 4 feet; not much mined.

Green Ridge Coal Co.

GREEN RIDGE COLLIERY.

(Works small area in city between Ash and Poplar Streets and between Monroe and Taylor Avenues.)

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
Clark		No schools over these workings	Formerly mined and caved; thickness, 8 feet; now being mined to recover pillars; openings being well filled with gob and surplus rock from lower beds; surface now settling somewhat in parts of this area; depth, about 175 feet. (See sections on Pl. 4.)
Dunmore No. 1		do	Depth, 248 feet (see sections on Pl. 4); thickness, 4 feet; mined, caved, and squeezed years ago; roof resting on old gobs; now being remined to win top coal formerly left; openings long filled, and surplus rock stowed in Clark bed. This upper split of No. 1 Dunmore is known at Manville and Dickson as No. 1, and bottom bench as No. 2 Dunmore.
Dunmore No. 2		No schools over this bed	Depth, 271 feet (see sections on Pl. 4); thickness, about 5 feet; known here as Dunmore No. 3; this bed mined and caved, and inaccessible under city.
Dunmore No. 3, China vein.		do	Mined and caved under city; now inaccessible; depth, 303 feet (see sections on Pl. 4); thickness, 3 to 4 feet.

North End Coal Co. colliery.

NORTH END COLLIERY.

(Works the upper beds near Leggetts Gap.)

Coal beds.	Name of school.	Mining conditions under school properties.	General conditions.
Beds above Diamond.		Eroded	Eroded.
Diamond	No. 23	do	Company remining old workings; now being worked along outcrop on steep dip and under mountain side, where few improvements exist on surface.
Rock	do	Outcrops under school; pitch, 45°; thickness, 3 to 4 feet; pillars, good size; conditions fair at present, but pillars should not be disturbed.	Company remining old workings (see sections on Pls. 11 and 13); thickness, $3\frac{1}{2}$ feet; divided bed in eastern part; top bench, 3 feet; rock, 3 feet; bottom bench, 3 feet 2 inches; dip of bed about 45°; crop falls liable on surface if upper pillars are removed.
Big	do	Pitch, 45°; bed outcrops about 100 feet north of corner of building; under center of building it is about 135 feet deep to bottom of bed; thickness, 18 feet or more; openings large, and should be filled; south side of school lot now protected by large pillar only partly under school lot; to southward—that is, down pitch from this large pillar—is immense excavation 24 feet high by nearly 90 feet square, only about one-sixth filled with falling rock and coal that has slid off from pillar.	Company remining old workings; thickness, 15 to 25 feet; dip, 45°; openings large; large crop caves liable to occur if pillars are removed.
New County	do	Depth, 275 to 336 feet; pitch, 50°; lowest workings are north of school; thickness, $1\frac{1}{2}$ feet; not mined under school.	Company remining old workings (see sections on Pls. 11 and 13); bed very thin; only mined near outcrop.
Beds below New County.		See Cayuga colliery, page 32	Not mined by North End colliery except in mountain side near outcrop.

Clearview Coal Co. colliery.

(Works South Providence north of Clearview Street, strip 200 feet wide, from North Main Avenue to Keyser Valley Branch of Delaware, Lackawanna & Western Railroad.)

This colliery is now engaged at second mining in the two top beds under above locality. These openings are expected to extend eventually under School No. 40, but will not reach this point for several years. The operation is small, and the output is delivered by wagons.

Bull's Head Coal Co.

(Works near junction of North Main Avenue with Providence Road.)

This colliery is engaged at second mining of the Diamond and the top split of the Four-Foot beds under Winton, Church, and Nassau tracts in above locality. No school improvements on these lands. Operation for local consumption, and delivery by wagon.

Mountain Lake Coal Co.

(Works on mountain side near Mountain Lake, east of Laurel line.)

This mine works an island of coal in Dunmore bed on mountain east of Laurel line, for local consumption; delivery by wagon. No surface improvements over the coal bed.

OBSERVATIONS ON PRESENT MINING CONDITIONS UNDER SCRANTON.

INTRODUCTORY STATEMENT.

As stated in the chapter on the history of anthracite, the mining methods pursued in the earlier days of the industry, not only in Scranton, but everywhere in the anthracite fields, were not conducted with the view of ultimately mining the maximum amount of coal, with the least effect upon the surface, but with a view to immediate profits. Hence, little attention was given to surveying and engineering in the early mines, and great irregularity in the method of mining was the rule rather than the exception. This irregularity makes it exceedingly difficult to columnize pillars now where mining is being done in the solid under worked-over portions of higher coal beds.

To illustrate this particular point reference is made to the tracings that show the mine workings under the various school properties and are in the possession of the board of school control. These tracings are included in the report made by Messrs. Stevenson and Knight. In the more recent mining under the city, the attempt has been made to remedy this defect, and this attempt has been fairly successful.

As the result of our inspection of the mines under Scranton, as given in detail on preceding pages, we have grouped the mine workings into several classes; in each of these classes approximately similar conditions obtain, and to each the same remedies for sustaining the surface might apply, as stated below:

SURFACE BEDS.

WEST SIDE OF LACKAWANNA RIVER.

On the west side of the Lackawanna River, at the Dodge, Hyde Park, Mt. Pleasant, Diamond, Brisbin, Cayuga, Von Storch, and Leggetts Creek collieries, the surface beds being mined are known as the Eight-foot, Five-foot, and two splits of the Four-foot.

As before stated there is only a small area underlain by the Eight-foot; the areas underlain by the other beds gradually increase in size, as the beds are lower in the measures.

In mining these beds efforts have been made—with a fair degree of success—to columnize the pillars, and about the usual percentage of coal, approximately $33\frac{1}{3}$ per cent on first mining, is left in for support of the overburden. In a few places reclamation of pillars, or what is commonly termed "robbing," is in progress, but only where there are comparatively few surface improvements. The menace to the surface from the mining of these beds, as at present conducted, is comparatively slight. When the time comes, however, for the reclamation of pillars from the greater part of the area mentioned, serious surface disturbance may be expected, unless in the meantime some method of support is introduced. Suggestions on this point are given on subsequent pages.

SOUTH AND EAST SIDES OF THE LACKAWANNA RIVER.

On the south and east sides of the Lackawanna River, at the National mine, the Big and the New County beds are nearest the surface under a part of the property, the Clark vein under another part, and the Dunmore No. 2 under still another part. The part underlain by the New County and Big beds carries few improvements and is much caved, so that no serious result is likely to occur by reason of the extraction of the remaining pillars. The mined-over part of the Clark bed, as will be noted from the plans, underlies a larger area than the mined-over part of either of the two overlying beds; and before extraction of pillars from the Clark bed is begun, measures for the support of the overburden should be adopted where the surface improvements are of sufficient value to justify the expense. This observation refers particularly to the part of the bed formerly worked from the old Meadow Brook mine; it underlies a thickly settled portion of the south side.

As will be noted on Plates 19, 20, and 21 the Dunmore No. 2 is the surface bed over a considerable portion of the National and Meadow Brook operations, extending from Beech Street to Sanders Street, and from the Erie & Wyoming Valley Railroad to the Lackawanna River. Examination of workings in this bed, and inspection of the mine maps, indicate that considerably less than the usual one-third has been left in pillars for support. There is no mining now in progress in this bed, nor any extraction of pillars. The pillars observed under the area mentioned (particularly between Beech and Breck Streets), and between Pittston Avenue and Crown Avenue, show signs of pressure and should not be disturbed. Although it is true that these pillars have stood without serious subsidence for many years, there is a possibility of a "creep" or "squeeze," such as would unquestionably cause surface damage in the area just mentioned, starting at almost any time. Remedial measures should be applied in the Dunmore No. 2 bed in this area at the earliest possible moment, before a creep or squeeze starts, as the conditions are such that if once started, no remedies that might be attempted, and hastily applied, would be effective in preventing a general subsidence of practically all the above mentioned area.

CENTRAL PART OF SCRANTON.

The Pine Brook colliery of the Scranton Coal Co. includes a large area in the central part of the city of Scranton, as will be noted from Plates Nos. 1, 2, 3, 4, 5, and 22. This area extends eastward from Beech Street on the south side to Poplar Street at the Dunmore line, and from the Lackawanna River to the outcrop of the Dunmore beds near Nay Aug Park.

Under a portion of the territory mentioned, the Big or Fourteen-foot bed is present. It was partly worked over many years ago by the old Lackawanna Iron & Coal Co. The area underlain by this bed is what is generally known as Sanderson Hill, and is clearly shown in Plates Nos. 2, 3, and 4. The old workings in the Big bed are inaccessible, except a very small portion that extends from the Pine Brook Traveling Way to a point under the Central High School. Although there may be other openings to the workings in this bed, they are unknown to us. From information furnished by various persons, it is believed that the old maps of the workings in this bed are reasonably accurate.

The part of these workings that was inspected showed the pillars in good condition and the roof over the openings fairly sound, although local falls have occurred in many openings preventing access to points beyond. According to our information no serious "creeps" or "squeezes" have occurred in this bed, and unless some disturbance takes place through subsidence of the measures below it not much danger is to be apprehended from a general creep in this bed. We are, however, of the opinion that detailed investigations should be made by reopening small holes through the local falls mentioned above, and by sinking shallow shafts at various points for the purpose of making accurate surveys of the mine workings. These should be maintained as avenues through which to conduct or transport material for filling. It is deemed especially important that these openings be completely filled, on account of the nearness of this bed to the surface, and the value of the surface improvements. Methods of protection will be described in another chapter.

Below the Big bed the next bed that has been worked from the Pine Brook shaft is the Clark. The New County bed has not been worked at Pine Brook, but it is present and will doubtless be mined in the future. The Pine Brook workings include what was formerly the property of the Fair Lawn Coal Co., between Gibson and Ash Streets, and Capouse and Quincy Avenues. The usual rule of leaving approximately one-third of the coal was generally followed in the major part of the workings from the Pine Brook shaft, but much less than one-third was left in the Clark bed where worked from Fair Lawn. This bed is from 8 to 11 feet thick; a bench of coal at about the middle of the bed that is considerably softer than the balance was noted. This bench is affected by what is known as "air slack," causing it to chip and flake off, and to show the first signs of any undue pressure on the pillars.

A very large proportion of the pillars inspected an this bed show unmistakable signs of pressure, particularly in the Fair Lawn workings and outwardly from this area for a considerable distance. These signs of pressure on the pillars can not, in our opinion, be solely attrib-

uted to air slack, but are, we believe, the first stage of a creep or squeeze that if fully started may result in the complete collapse of the pillars in a large part of the area mentioned; it would bring down the roof, and unquestionably affect the surface. These indications, as before stated, are most serious in the Fair Lawn workings; they are observed on both sides of the tract and under the portion of the property where the Big Vein is present. Should a general squeeze take place in the Clark bed workings it would certainly affect the pillars and overlying strata of the Big bed and result in a very serious disturbance of the surface.

We deem it important to lay particular stress on the necessity for promptly taking measures to prevent the *starting* of a general squeeze or creep in the Clark bed at the Pine Brook colliery; for such a squeeze might cause breakages of gas, water and sewer mains, and resultant damages.

A point of particular weakness in this bed is under the Technical High School, near the intersection of Adams Avenue and Gibson Street. We have been informed that the Scranton Coal Co. has begun flushing culm into the workings under this important building, and that it is their intention to fill these workings as rapidly as possible. When this flushing is completed and a block of 1 or 2 acres is completely flushed, it will strengthen not only the point immediately filled, but have a tendency to support the roof for some distance on all sides of the artificial pillar thus introduced.

The old Lackawanna Iron & Coal Co. opened and worked the Clark bed by a drift from Roaring Brook gorge, near the Laurel line station. These old workings are now inaccessible, but maps inspected show an area worked over on the north and east sides of the river bank between the Delaware, Lackawanna & Western Railroad and Vine Street, and Madison and Clay Avenues. The maps show that very small pillars were left in. The old workings should be opened and artificial pillars made by flushing. The same plan is suggested for the Big, or Fourteen-foot, bed under Sanderson Hill, and for the old Iron Co. workings in this bed on the south side of Roaring Brook, under Spruk's lumber yard and vicinity.

At the Manville colliery, operated jointly by the Delaware, Lackawanna & Western and the Delaware & Hudson Companies, the surface bed is the New County. This bed has been attacked recently, and is now being mined under the Green Ridge section of the city. It averages about 6 feet thick, with nearly 2 feet of refuse in several benches. We were informed that under the old leases the lessees were prohibited from mining this bed, but by a recent modification of the terms of certain of the leases they are permitted to extract one-third of the bed, leaving two-thirds as pillars to support the overburden. Considering the depth at which the bed lies and the char-

acter of the overlying strata, we do not think there is much danger to the surface from mining this bed, if not more than one-third of the coal is extracted.

At this colliery the Clark bed has been worked over the whole of the area tributary to the mine, as will be noted from Plates 5, 6, and 7, and is at present abandoned, no solid or pillar mining being in progress. About the usual one-third of the coal has been left to support the roof. Many parts of these workings are inaccessible because of local falls, and a small part of the workings has been filled with culm, principally under surface improvements controlled by the mining company.

The pillars in this bed show the usual chipping, due to air slack, and in some places signs of squeeze or creep, particularly in the vicinity of Poplar Street and between Capouse and Washington Avenues. The boundary pillar between the Manville workings and those of the Pine Brook mine is very small, and would not be of sufficient strength, in our opinion, to break off or stop a squeeze that might originate on either side of it. We are of the opinion, therefore, that filling or other remedial measures for the support of the overburden should be started in portions of the Manville Clark-bed workings, as we recommended at Pine Brook.

At the Dickson mine of the Delaware & Hudson Co. the surface bed is the Big, or Fourteen-foot, which is 10 to 14 feet thick. This bed was worked some years ago between the river and Dickson Avenue and between Delaware and Market Streets; a very small part east of Sanderson Avenue was also worked.

No mining, either of solid coal or pillars is now being done in this bed. There is, however, a considerable block of solid coal east of Sanderson Avenue that may at some time be extracted. If mining is resumed in this bed it should be conducted with great care, as the bed is close to the surface, and the overlying strata are weak.

Parts of this bed west of the Delaware & Hudson Railroad and under the Lackawanna River have been flushed with culm, and the balance of the workings should be filled in the same manner. The possibility of recovering the pillars in the worked-over part of this bed without serious damage to the surface is, in our opinion, decidedly doubtful, even though the openings may be completely filled with culm or other flushed-in material.

The New County bed has not been worked at the Dickson mine, being considered too thin and impure for profitable extraction. This bed, however, may be mined hereafter.

The Clark bed has been mined in about the same manner as at Pine Brook and Manville, and the same remarks regarding conditions apply. Portions of this bed also have been filled with culm, particularly toward the Lackawanna River.

MIDDLE BEDS.

HYDE PARK AND PROVIDENCE SECTIONS.

As before mentioned, under Hyde Park and Providence, the middle series of beds, the Diamond, Rock, Big, New County, and Clark (especially the first three of these), are quite thick and the intervening strata are comparatively thin and weak. On account of the failure in the past to columnize pillars, the workings in these beds, where now open, constitute a serious menace to the surface, and this portion of the city will be the most expensive and difficult to protect. However, it should be noted that very large areas of the three uppermost beds have been closed by crushing of the pillars and strata in the past. This condition was observed in parts of the Bellevue, Hyde Park, Hampton, Oxford, Mount Pleasant, Diamond, Brisbin, Cayuga, Von Storch, Leggetts Creek, and Marvine mines. Where such complete crushing of the pillars, with consequent subsidence of the overlying strata and surface, has taken place in the past, no serious apprehensions need be entertained of future damage to the surface improvements, unless, in the process of mining lower veins, insufficient pillar support is left to carry the overburden and a creep or squeeze takes place. This has been the case recently at the Leggetts Creek mine in mining the lower Dunmore bed at a depth of 700 feet, where was applied the usual though here insufficient rule of leaving about one-third of the coal for support.

Where the workings in these thick and closely lying beds are not closed by a general crush (and no one knows how large or extensive such openings may be) there is always a liability to a repetition of the same kind of subsidence as that which wrecked No. 16 School. In this connection attention is particularly called to the conditions existing under No. 12 School. Here the Diamond bed is very near the surface, within 13 to 40 feet. Second mining is now in progress to win bottom coal formerly left in this bed, and the New County bed is being mined. An attempt is being made to drive openings in the New County bed under openings in the Big bed, but this attempt is not altogether successful. These conditions, we believe, are quite similar to those formerly existing under No. 16 School.

We strongly recommend that the pillars in the Diamond, Rock, Big, and New County beds under this building should not be disturbed, and that the openings in the Diamond, Rock, and Big beds should be filled as promptly as possible. Such filling could easily be done by drilling one or two bore holes in the school lot. The filling of openings should not be confined to the school lot only, but should extend outside the lot some distance, as there is danger in case of a cave in any seam, of the side pull damaging the building.

It is also deemed important to refer particularly to No. 23 School, where the Rock and the Big bed pillars now in place should not under any circumstances be disturbed, neither under the school lot nor for some distance outside of it, as shown by the maps formerly submitted to the school board by the North End Coal Co. We also suggest that the openings under this school property should be flushed full of sand, culm, or other material.

The best manner of applying an effective remedy for this serious menace is difficult to determine, because the openings are so large, on account of the thickness of the seams, and there is the difficulty of procuring the material for this purpose.

DUNMORE BEDS.

The deeper-lying Dunmore beds under the major portion of the city, constitute a class by themselves. They are in many places so thin that during mining much top or bottom rock has been removed in all the gangways and along roads in the chambers to make room for cars and mules. This rock with the large quantity of interstratified refuse that is usually present in the coal beds nearly fills the mined-out space when stowed in the chambers, and thus constitutes a check to quick or total subsidence. Then, too, the thickness of the rock over the coal is generally so great that local caves in the workings are not likely to affect the surface. The greatest menace to the surface property from these deep thin beds is through a general subsidence—a creep or squeeze extending over large areas. Even then the settlement will be gradual, and as a rule so uniform as to cause little or no damage to surface property, except where the uniformity of the subsidence is interrupted or prevented by the presence of very large pillars or solid blocks of unmined coal, in which event, buildings located on the surface over or near the margin of such large pillars will be liable to considerable damage by the side pull, or uneven subsidence.

In consequence of these facts we would advise as a measure of preventing damage to surface improvements over these deeper beds that the Dunmore beds be mined in the usual manner under large blocks of coal now held as reservations in any of the coal beds overlying the Dunmore and not at present mined nor intended to be mined.

RECAPITULATION.

Thus, to recapitulate, we have three general sets of conditions which naturally divide the coal workings into as many separate classes, to wit:

1. The surface beds, viz, on the west side, the Eight-foot, Five-foot, and Four-foot; on the east side, the Big, New County, Clark, and Dunmore No. 2, of which the latter are surface beds under different parts of the south side and central city sections.

2. The middle series of beds, viz, Diamond, Rock, Big, New County, and Clark, under the Hyde Park and Providence sections.

3. The three lowest beds, Dunmore No. 1, Dunmore No. 2, and Dunmore No. 3, under the major part of the city.

METHODS FOR SURFACE SUPPORT.

The methods employed at the present time for supporting the surface over the coal mines under the city of Scranton are of two general classes, which may be termed natural and artificial.

NATURAL OR PILLAR SUPPORT.

The natural method, of course, consists in leaving pillars of coal sufficiently strong to support the weight of the earth and rock that overlie the coal bed. The efficiency and value of these supports depend upon their size. That is, the horizontal area, the height of the pillar (which is fixed by the thickness of the coal bed), the compressive strength of the coal, the regularity of distribution of the pillars, and whether or not they are columnized with respect to pillars in near-by overlying or underlying beds, all have to be considered. In this vicinity the size of pillars has been mainly regulated by the one-third rule previously mentioned.

ARTIFICIAL SUPPORT.

FLUSHING.

There are several artificial methods of roof support, the principal and most effective of which is known as the flushing method. In this method coal culm and other fine refuse is washed into the mines through pipes by means of a stream of water, thus filling the desired portions of the mine.

This method was first used at Shenandoah, Pa., by the Philadelphia & Reading Coal & Iron Co. Afterwards it was introduced at Plymouth, Pa., and now has been adopted and is in practice over the whole anthracite region. Only culm is used, and the method has been adopted mainly for the purpose of protecting those parts of the mine or of the surface which it is necessary to support in order to maintain the mining operations.

Under Scranton considerable flushing has been done at various places, as indicated in the chapter on "Present mining conditions." Foreign engineers, after inspecting the process in this country, have adopted it in Europe. There, much extended and amplified, it is now an essential part of the more recent mining methods by which the engineers are able to recover all the coal; the excavated spaces are filled by the flushing method with crushed rock, sand, gravel, and soil obtained from quarries opened for the purpose, and also with ashes and city refuse, some of which is transported long distances over the surface to the flush pipes. Foreign engineers

find that when they thus remove all the coal, a gradual though small surface settlement results, the amount of which depends upon the depth and the thickness of the coal. In this country, however, we can not hope to profitably use such expensive mining methods as may obtain abroad, because the cost of labor in the United States is very much greater and the market price of coal very much less than in Europe. The appearance of culm flushing is shown by Plate 26.

COGS.

It is frequently necessary in the course of mining to make use of some roof-supporting device that may be quickly constructed and is withal possessed of great strength. The timber crib filled with mine rock—known in mining parlance as a "cog"—has been found to answer these conditions in a very satisfactory manner, and is extensively used in all coal-mining districts. The cog consists simply of a rough crib of stout logs placed one above the other, log-house fashion, the spaces between the logs being chinked and the interior being filled with rock from the mine. (See Pl. 27 *A*.) This construction is quickly erected, and possesses great strength. Of course it is not permanent because the timbers decay in a few years. Cogs are mainly used for the purpose of stopping a settlement, squeeze or creep which the mine foreman knows to be imminent or in progress. A view of a squeezed area in the Dunmore bed is shown in Plate 29 *A*. When sufficient cogs are placed in proper localities the strata above the bed will frequently crack through to the surface, and the progress of the squeeze or creep will thus be stopped.

GOB PIERS.

Gob piers are pillars built of such refuse rock as may be readily found in most mines—mainly bony coal, fire clay, and slate. Such rock is mostly soft and does not possess very great compressive strength. Some of these piers have a square outer or inclosing wall, and are filled with mine refuse shoveled into them. In others the interior is laid up by hand and the rocks are more carefully compacted by filling the voids with fine mine refuse.

A great many such piers have been built under localities in the city of Scranton for the purpose of supporting the roof under valuable surface improvements. (See Pls. 27 *B* and 28.) The value of such piers, that is, their supporting strength, depends upon the compressive strength of the materials of which they are constructed. The value will be greater if the voids between the larger pieces are filled with the small rock and shoveled material from the mine.

GOB STOWAGE IN ROOMS.

Most coal beds consist of interstratified layers of coal, fire clay, slate, and bony coal; the three latter, of course, compose the prin-

A. GANGWAY CUT THROUGH CULM FLUSHING, OXFORD MINE.

B. GANGWAY CUT THROUGH FLUSHING, CULM STANDING AS A VERTICAL SELF-SUSTAINING WALL, OXFORD MINE.

A. TIMBER AND ROCK COG, IN BELLEVUE MINE.

B. GOB PIER IN DUNMORE NO. 2 BED, NATIONAL MINE.

cipal refuse material of the mine. In all the mining methods adopted under the city of Scranton, all the material of the coal beds that is not coal is laid aside as refuse and stowed away in the chambers, either on one side or on both sides of the mine tracks. In thin beds where it is necessary to remove some of the roof rock or take up some of the floor of the mine in order to obtain height sufficient for the mules and the men to travel along the roads, much mine refuse is produced, which is also stowed in the chambers. In beds less than 4 feet thick many chambers are filled with mine refuse or gob, as it is more familiarly termed, from floor to roof. In places this gob is merely thrown in carelessly, or is shoveled in; in other localities it is packed as tightly as possible by hand. It frequently happens that the whole chamber from pillar to pillar is packed full of mine refuse. Where there is much interstratified fire clay or bone in the coal bed there will be larger quantities of the gob, and the thinner the bed the greater will be the quantity of mine rock raised or taken down for roads. Consequently, this stowage of gob in the rooms of the mines under the city of Scranton becomes an important item when the support of the surface over these coal beds is considered. As in the case of the gob piers and the cogs, the supporting value of stowed gob depends upon the compressibility of the material of which it is composed.

CONCRETE AND MASONRY PIERS.

The above methods of artificial support already mentioned are comparatively cheap to install. Some other methods of support used in the city of Scranton are concrete and sandstone piers. In these the material for construction has been introduced from the surface (through bore holes in the case of concrete or through shafts from the surface in the case of blocks of sandstone), and in the mine has been wrought into substantial piers by the use of cement. (See Pl. 29 *B*.) Though these forms of piers are much more substantial than those previously mentioned, they are also much more costly; consequently fewer of them have been installed.

IRON PROPS.

In one place, namely, in the Big bed under the Central High School building in this city, a number of iron props or posts have been installed as additional roof support. There has been no subsidence of pillars in the locality where they have been used; therefore the supporting value of the props has not been tested and their efficiency is largely a matter of opinion. In any case they are costly to install, and it is entirely probable that much more efficient means might be used for the same purpose at less expenditure.

TESTS OF ROOF-SUPPORTING DEVICES.

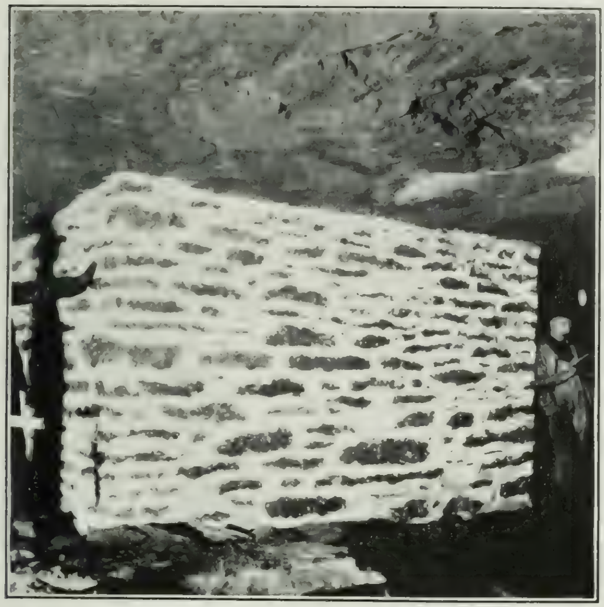
COMPRESSIVE STRENGTH OF ANTHRACITE.

In 1903 an exhaustive series of tests was conducted under the direction of a committee of the Scranton Engineers' Club for the purpose of determining the compressive strength of anthracite coal. The report of this committee on tests is printed in an appendix (see p. 77) to this report. The results, however, may be summed up briefly in the statement that a pressure of 216 tons per square foot will cause the average ordinary mine pillar to begin cracking, and a pressure about twice as great (432 tons per square foot) will crush it to powder.

This general statement, however, does not apply equally to all coal beds, for the tests prove a great variation in strength, even between different parts of the same bed. In some instances the weight required to crack the pillars was as low as 30 tons per square foot.

TESTS AT LEHIGH UNIVERSITY.

In order to test the value of the several artificial devices for supporting the roof of a coal mine, as well as to search out an inexpensive combination of materials which might be more cheaply installed and withal more permanent and efficient, and better adapted to certain localities than some of those mentioned, we prosecuted a series of tests at the Fritz engineering laboratory at Lehigh University, South Bethlehem, Pa., the results of which are also given in an appendix (see p. 83) to this report. A tabulated summary of the results follows, and from it mining engineers may readily compute the supporting value of any particular construction.



A. A GOB PIER IN CLARK BED UNDER CENTRAL HIGH SCHOOL BUILDING, PINE BROOK MINE.

B. SIMILAR PIER WITH FLUSH PIPE PASSING THROUGH SHOWS SUPERFICIAL CHARACTER OF MORTAR POINTING.

A. VIEW IN SQUEEZED AREA IN DUNMORE BED, LEGETTS CREEK MINE.

B. SANDSTONE AND CEMENT MASONRY PIER IN DUNMORE NO. 2 BED UNDER SCHOOL NO. 15, NATIONAL MINE.

TABLE 3.—*Results of tests of compressive strength of various forms of roof support.*

No. of test.	Construction tested.	Net tons per square foot required to produce compression of—						Compression and load (tons per square foot) at end of test.	Remarks.
		1 per cent.	3 per cent.	5 per cent.	10 per cent.	20 per cent.	30 per cent.		
1	Rectangular piers of mine rock	....	0.8	1.4	2.7	9.5	23	....	Average construction; voids not filled.
2	Circular pier of mine rock	....	3.5	5.67	11	22	38.5	Compression, 31 per cent; load, 42.5.	Well constructed; voids filled with small and shovel stuff.
3	Timber crib filled with mine rock	....	.6	1.37	5.11	20.3	31.5	....	Average construction.
4	Pile of broken sandstone; small pieces	....	....	....	4	9.3	22.4	Compression, 46 per cent; load, 104.5.	
5	Pile of small-size broken sandstone and sand.	....	....	1.6	4	13.5	35	Compression, 45 per cent; load, 144.	
6	Pile of broken sandstone; large pieces	....	3.6	5	9.1	26.4	37	Compression, 41 per cent; load, 75.	In these tests the material was not confined, but was free to expand laterally. (See appendix, pp. 84-86.)
7	Pile of coal-measures sandstone similar to No. 6.	0.8	2.1	3.5	9	33.4	....	Compression, 27 per cent; load, 56.	
8	Pile of river sand	....	....	....	....	....	....	Compression, 63 per cent; load, 108.	
9	Broken sandstone in cylinder	....	3.33	5.55	13.32	46.6	98.6	Compression, 35 per cent; load, 666.	
10	Broken sandstone and sand in cylinder	....	3.5	5.77	24.42	308.5	....	Compression, 23 per cent; load, 686.	
11	Dry coal ashes in cylinder	....	1	1.86	5.32	10.8	25	Compression, 51 per cent; load, 666.	In these tests the material was confined and could not expand laterally. (See appendix, pp. 86-88.)
	Coal ashes flushed in with water	....	....	....	....	5.50	22		
12	Wet culm flushed in cylinder; partly dried (average of two tests).	2.44	8.9	14.28	35.52	138.7	444	Compression, 33 per cent; load, 668.	
13	Dry sand in cylinder	.88	3	5.27	33.3	129	499	Compression, 32.2 per cent; load, 666.	
14	Wet sand flushed in and partly dried	8.4	39.3	67	173.8	555.4	....	Compression, 20.75 per cent; load, 666.	
15	Concrete made of cement, sand, and gravel; 4 months old; 1 barrel Portland cement to each cubic yard of concrete (about one part cement to seven parts sand and gravel); piers 3 inches by 2.81 inches by 3.85 inches high.	9 Cracked.	84	Gradually crushed to pieces under continuous load of 45 tons.					This test was made at the Dickson Works of the Allis-Chalmers Co. in Scranton, by William Griffith.

DRY FILLING.

Although we recognize that the flushing process is the most substantial method for artificially supporting the roof of coal mines, and that it is also universally suitable for thin or thick beds and deep or shallow beds, nevertheless the method is not always applicable or convenient. There are many localities in the coal mines where it may be either preferable or permissible to resort to some of the other less efficient or less costly methods of roof support, which for one reason or another are more adaptable to a particular locality. Therefore we refer to the improvements that may be made in the different methods of dry filling.

IMPROVED METHODS OF GOB STOWAGE.

Formerly the gob of coal mines was disposed indiscriminately over the chamber at the side of the roadway, mainly for the purpose of getting rid of it at as little cost as possible. A casual inspection of the comparative table of tests on page 55 will show that well-constructed gob piers are much stronger than those indifferently built. It is also evident that in supporting the roof of coal mines, as well as in other matters, "an ounce of prevention is worth a pound of cure." The effort, therefore, should be to prevent the first small settlement, and the way in which to accomplish this effort as far as possible in the matter of stowage will be to pack the rock fragments carefully and tightly against the sides of the pillars from floor to roof, irrespective of the horizontal area occupied, and to use the fine refuse, so far as may be, to fill the voids. If the gob now contained in the thinner seams under the city of Scranton had been carefully packed so as to completely fill the space from floor to roof it would not only reinforce and preserve the strength of the coal pillars, but would present very much greater resistance to pressure and would be a much more efficient roof support than is afforded by the usual present stowage with 1 to 2 feet of space between the top of the stowed gob and the mine roof.

In some beds now working there is a surplus of mine rock which can not be stowed in the chambers and must be hauled out into other parts of the mines. If it is determined to continue thus to stow this material instead of hauling it to the surface and grinding it for flushing purposes, as has been previously mentioned (see p. 55), the purpose of roof support would be better served if the places for depositing this surplus stowage were selected with reference to the weak parts of the mines, or with reference to the support of the ground under some particularly valuable surface improvement.

Commendable work is being done along this line at the Cayuga mine of the Delaware, Lackawanna & Western Railroad; the pillars

are being extracted in a surface bed and the space formerly occupied both by the chambers and the pillars is being completely filled with surplus rock taken from a lower bed.

BLASTING ROOF AND FLOOR IN THINNER BEDS.

It is a well-known fact that loose rock occupies one and two-thirds to two times the volume of the same weight of solid rock. In other words, if a cubic yard of solid rock be broken to pieces the pieces will occupy a space of 1⅔ to 2 cubic yards.

We have conceived the idea of taking advantage of this fact for the purpose of cheaply producing an adequate roof support for certain classes of coal beds under the city. So far as we know, this method, in its entirety, has never been used before in any coal-mining district, and the suggestion is here made for the first time.

The process would be applicable to beds less than 6 feet thick and so situated that the shock of heavy blasting would not produce ruptures of the measures supporting adjacent coal beds. It consists simply in blowing up the floor of the mine to a depth equal to the thickness of the bed, and blowing down the roof of the mine directly over, to a height equal to the thickness of the bed. This would produce a total thickness of loose rock equal to three times the thickness of the coal bed. The rock would be well packed together and have great supporting power, and the process would be comparatively inexpensive.

This method might be adopted throughout the Dunmore and other thin seams, by blasting down the roof and raising the floor in the abandoned rooms or the roadways between the gob piles in the chambers. Wherever it is applied the effort should be to completely fill the whole width of the chamber or roadway from pillar to pillar, so that the loose rock will be confined between the pillars, thus greatly increasing its resistance to compression. The value and supporting power of this method of roof support and of other methods will be referred to below.

GOB PIERS AND TIMBER COGS.

There are localities under the city of Scranton where it has been deemed advisable in the past to build gob piers for the support of the roof overlying certain surface beds. The Lehigh University tests mentioned in this report show that this method of support lacks the merit of strength. The piers are very compressible, and as they have been built heretofore their supporting value is small. Their efficiency would be greatly increased, as shown by the differences between test No. 1 and No. 2 (pp. 83–84), by building them in circular form and carefully filling all the voids between the larger pieces with smaller particles of shovel stuff.

CONCRETE PIERS.

During the progress of this investigation many persons have called our attention to concrete piers as suitable for firm roof supports. This material is so costly, however, that we have hesitated to recommend it except perhaps in special cases where very valuable surface property requires unyielding support and the expense of such support is no object.

We have tested the strength of one sample of concrete composed of about the cheapest good materials available for this locality, i. e., cement, sand, and gravel. The results of this test are shown in Table 3, test 15, and Table 4, test 14 (pp. 55, 59). It will be noted that such concrete is firm and comparatively unyielding up to a certain maximum strength sufficient to cause about 3 per cent of compression and cracking, beyond which a much less weight will crush it to powder. This latter characteristic is an exceptionally bad one for a mine roof support, because such piers are liable, under the excessive stress due to a general squeeze, to collapse quickly, and thus permit the sort of caving that resembles a small though severe local earthquake in its suddenness and excessively damaging effect on the surface improvements.

DRY FILLING WITH BROKEN STONE OR SAND.

For the construction of isolated and more substantial low-cost piers in the surface beds under the city, to take the place of the gob piers for the purpose of the local support of valuable surface improvements where general flushing is not convenient, we strongly recommend the filling with broken stone or sand, or a combination of these materials, through bore holes from the surface.

Filling of this sort should be spread out by hand in the inside of the mine so that it completely fills the whole width of the space from pillar to pillar, and thus, being more or less confined has its supporting power increased. If broken stone is used the relative proportion of the voids should be ascertained and an amount of sand, coal ashes, or other fine material added sufficient to fill these voids.

By this method one bore hole 4 to 6 inches in diameter would be necessary for each pier, and inasmuch as these materials, if flushed in by water, are much more closely packed and have from ten to fifteen times the compressive strength of dry filling, it would always be wise, if water is handy or is not too costly, to flush the material in, using in some cases the city water, or the water from the gutters during the storm seasons for the purpose. The more sand there is in the mixture the better it will be, for our tests have shown that clear river sand is the strongest and least yielding material available, if it is flushed into and confined in the limits of a mine chamber; moreover it is about the cheapest material obtainable for this purpose in Scranton.

THE VALUE OF THE DEVICES FOR ROOF SUPPORT.

The following table sets forth the value of the above devices for dry filling, and also the value of the different materials that are available for flushing coal mines in this locality. The values are directly deduced from the results of the tests made by us at Lehigh University, and we think are sufficiently clear to be self-explanatory. We might add, however, that test 1 would represent the ordinary supporting value of gob piers or gob pillars. Test 2 represents the value of well-constructed gob piers, while tests 6, 7, and 8 set forth the supporting value of mine rooms filled with rock blasted from the floor and roof, as heretofore mentioned; and tests 12 and 13 indicate the supporting strength of fine materials, such as coal culm and river sand, if flushed in with water. At the bottom a comparison is made between the supporting value of the flushed culm and the flushed sand, and the concrete piers of the same nature as the sample tested.

TABLE 4.—*Supporting strength of various forms of dry filling.*

Kind of material comprising the artificial supports.	Approximate depth, in feet, of column of coal measure rock 1 foot square, necessary to compress artificial roof supports—						Remarks.
Per cent of compression	1	3	5	10	20	30	
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
1. Rectangular gob piers, ordinary construction	......	10	12	36	125	306	Free to expand laterally.
2. Circular piers of mine rock well constructed	......	46	75	146	292	512	
3. Timber cogs filled with gob, average construction	......	8	68	182	270	419	
4. Loose pile of broken sandstone through 1¾-inch ring, 40 per cent voids	......	....	20	53	124	298	
5. Pile broken sandstone, 40 per cent voids, voids filled with sand	......	....	21	53	186	465	
6. Loose pile large size broken sand rock, 45 per cent voids	......	48	66	121	351	492	
7. Mine room filled with large broken sand rock, 50 per cent voids	12	27	45	117	434	[a] 615	
8. Mine room filled with broken sandstone, 40 per cent voids	......	44	74	177	619	1,310	
9. Mine room filled with broken sandstone, 40 per cent voids filled with sand	......	46	77	325	6,000	[b] 8.860	
10. Mine chamber filled with dry coal ashes, 64 per cent voids	......	13	25	70	143	332	
11. Mine room filled with dry river sand.	12	40	70	442	1,715	6.640	
12. Mine room filled with river sand flushed in with water	111	522	891	2,310	....	[c] 8,860	
13. Mine chamber filled with coal culm flushed in with water	32	118	190	472	1,822	5.905	
14. Concrete pier, 1 part cement, 7 parts sand and gravel; 5 months old	117	1.092	Gradually cracked to pieces under continuous load equal to 600 feet of rock.				
Resistance of flushed culm	1	1	1	1	1	....	Comparative.
Resistance of flushed sand	3.5	4.4	4.7	5	4	....	
Concrete pier	3.6	9	([d])	([d])	([d])	([d])	

[a] 27 per cent settlement.
[b] 23 per cent settlement.
[c] $20\frac{3}{4}$ per cent settlement.
[d] Worthless.

SUGGESTIONS FOR IMPROVEMENT IN MINING METHODS AND PILLAR SUPPORT.

The solid coal remaining to be mined under the city of Scranton is mainly in the Dunmore beds Nos. 1, 2, and 3. These beds are from 200 to 600 feet below the surface under the greater portion of the city.

Future mining plans, we think, should provide for leaving at least 50 per cent of the coal in these beds on first mining, and the columnization of the pillars throughout all new mining as far as possible.

FLUSHING.

Reference has been made to the practice, now quite general, of flushing culm into the mines. This is being done at nearly all of the collieries within the city limits, and the method and effectiveness of this kind of support was observed by personal inspection underground (see Pl. 26).

With reference to the tests made at Lehigh University of the compressibility of the several kinds of support now in use or suggested, we are of the opinion that a practicable method for the support of the overburden, utility and cost being considered, is flushing the openings with culm, ashes, sand, broken stone, material excavated from cellars, and other stuff of similar nature that can be reduced to a size small enough to be carried in pipes with water.

As before referred to, the flushing of mines for the support of the overburden has been adopted in Europe with marked success, both in the matter of support and recovery of all the mineral, the material used for filling being sand, loam, crushed slag, and crushed stone.

It is manifest that the quantity of culm available for flushing the extensive mine openings is insufficient, even if all of that now on the surface within the city limits, together with that produced in the preparation of the present output of coal were put into the mines.

According to figures we have assembled and supplemented with estimates, it appears that there has been extracted from the beds underlying the city, approximately 221,000,000 tons of coal and other material.

The workings under the city are, of course, not all open, large areas having been closed by general caves and squeezes. It is not possible to determine the proportion of openings that have been thus closed or filled, but a conservative estimate of the space now open would be that it probably does not exceed 50 per cent of the original.

The positive protection of all of the surface would appear to require the filling with some supporting material of all of the open spaces as rapidly as the coal is extracted; but such a scheme is, of course, impracticable. It therefore remains to determine about what

proportion of the openings to be flushed would afford reasonable protection. To determine this point definitely would necessitate a much more thorough investigation and more detailed surveys than were contemplated in the general investigation upon which we are now engaged. We would, however, express the opinion that conditions could be materially improved by the insertion of artificial pillars reinforcing the natural pillars of coal in blocks of from 1 to 5 acres at points where the danger of subsidence appears greatest; such artificial pillars to be arranged with some degree of regularity, so that the overlying strata between the artificial pillar supports would act as natural bridges. This suggestion is made in order to distribute the relief measures over as large an area as possible, and to keep the burden of expense within reasonable bounds.

The fact that the best and most practicable of supports is obtained by flushing refuse material into the openings having been determined, it remains to ascertain the sources of supply of this material, and the practicable methods of handling it.

We would classify the materials obtainable, in about the following order:

CULM FROM OLD AND FROM FRESH-MINED BANKS.

Culm is now being used for flushing mine workings. We make no further comment, excepting to refer to the test of its compressibility, and to the fact that we had opportunities to observe the methods of distribution of the material underground, and to note the apparent support given to the existing coal pillars and to the overburden.

SURPLUS MINE ROCK.

The second source of supply of material, in the order of availability, we believe would be the surplus mine rock that is produced in the mining of the thin beds of coal where either roof or floor must be removed to make height. It was observed in most of the thin beds visited that considerable quantities of this material are handled, either being stowed in the chambers or loaded into mine cars and hauled to some distant point to be unloaded by hand into abandoned mine openings. While this stowage of gob affords some measure of support to the coal pillars and the roof, the compressibility of the material, as shown by the tests, is so great that the material if put in by ordinary stowage is practically useless as an effective support, particularly at great depths. We believe, therefore, that this material should be loaded into cars, hauled outside, and handled over an efficient dump and through crushing rolls of proper design for pulverizing hard materials. The ground material should then be flushed, with the culm produced at the mine, into the portions of the mine workings where it will do the most good.

In addition to this source of supply of filling material, it would probably be found practicable to install handling and crushing machinery at each of the mining operations within the city limits, to pick up refuse material, such as old rock banks, ash banks and slag, and to grade off humps and hills of earth and comparatively soft rock, and to treat this material in the same manner. The cost of handling and flushing such foreign material in connection with the going operations of the several mines, would, of course, be very much less per cubic yard than it would be in the case of an independent plant established for obtaining and handling flushing material elsewhere.

RIVER SAND.

The next source of supply of material for flushing purposes, and one that we deem of considerable importance, is the Lackawanna River. It is a well-known fact that this stream of water carries in suspension large quantities of culm, sand, and loam at all times, and especially during the flood season. Of course it is impossible to determine without careful tests the quantity of this material in cubic yards, but we do not hesitate to express the opinion that there is enough of it, and will continue to be, to justify the establishing of settling basins and of a pumping plant for distributing the material thus impounded to points in the mine workings where artificial pillars are to be inserted.

To utilize this source of supply, it would, in our opinion, be advisable either to purchase, or to procure long-term leases on, river-bottom lands at various points where suitable catch basins could be excavated, and to procure a site for a central pumping plant for the purpose of handling this material. When such a plant is established, arrangements could be made to let down from the catch basins, at points upstream, the accumulated material; this would be carried by the stream to a central basin somewhere within the city limits.

We believe similar impounding basins on a smaller scale might be practicable on Roaring Brook, and that such material, if gathered at a higher elevation, might be flushed to near-by mine workings by gravity.

CITY REFUSE.

Another source of supply of material for flushing purposes would be city ashes and refuse from the streets and catch basins; also material from cellar excavations, grading of streets, parks, etc., which of course would have to be put through a crushing plant and reduced to such a size that it could be handled by flushing. For the proper distribution of the material just mentioned it would be necessary to drill bore holes to the mine workings at convenient points in the city streets and alleys—preferably in the latter, because there would be less inter-

ference with traffic. The necessary water for flushing this material would, of course, be supplied from the central pumping plant on the river or from the Roaring Brook gravity supply.

SAND FROM DISTANT POINTS.

Another important source of supply of material which we believe would be practicable would be sand and loam that the transportation companies should bring in from distant points along their railroads, where it can be most economically procured, in returning empty coal cars. This material would have to be dumped over a suitably arranged hopper and flushed into the mines with culm and other material.

A comparatively cheap and effective means for transportation of flushing material on the city streets to the shallow shafts and bore holes suggested would be to arrange with the traction company to haul the stuff in suitably designed hopper-bottom cars from the central crushing plant during the time of light traffic at night.

We would suggest the establishment of about four crushing plants so designed as to be easily knocked down and moved to other locations. The material to be handled by these plants should be taken from points where grading of humps and hills will result in the improvement of highways, parks, and private or public lands.

In this connection we would refer to the very extensive grading operations carried on in Seattle, Wash. A large section of the business center of that city was regraded mainly by the hydraulic method. Hills 100 feet high were cut or washed away, buildings were shored up or torn down, and the general level of the regraded section was lowered 10 to 30 feet. The material was flushed into Puget Sound by streams of water, and large areas of new land were formed over the low tide marshes along the bay shore. The expense was met by a general city-improvement tax.

PLANS, SPECIFICATIONS, AND COSTS.

The general nature and wide scope of this report necessarily limit us to general plans, specifications, and estimates of cost. The rendering of detailed plans and specifications and of exact estimates of cost can be made only after careful and exact surveys under particularly ascertained conditions; such surveys should be obtained from the engineers who are to be in charge of the execution of the work recommended in this report, in case it shall be entered upon by the authorities. We therefore explain by way of specifications what will be necessary in our opinion, what we recommend to be done to ameliorate the present conditions, and the approximate cost thereof.

We have made careful investigations of the resisting power of the various devices thus far used for supporting the roof at various

places under this city, and also of other devices we were cognizant of or have ourselves originated, but the supporting values of these various devices, as indicated in the tables of tests presented, have convinced us that the method of flushing material into the mines by means of water is the best and only well-tried method.

The method we have originated and experimented upon to some meager extent—that of providing roof support by simultaneously blasting the floor and the roof of the coal mine to form a permanent pillar from the débris resulting from the blasting—is an economical one, and has its advantages for certain special localities where the overburden is light. Still, the amount of compression to which the pillars of this sort would be liable is considerable and the extent of the possible disrupting effect of the heavy blasting upon the strata is unknown. Consequently, much more extended and practical experiments or tests of the method must be made before its value and importance as a roof supporting device can be established.

Therefore, the only method we feel like recommending, after a careful study of the conditions, is the flushing method.

As before mentioned, the best protection for the surface from caves would require the complete filling of the mine openings with culm, sand, or other form of material, and even then there would be more or less subsidence if pillars were removed and filled-in material were substituted. The excessive cost of completely filling the openings, and the tremendous magnitude of the project makes this plan prohibitive.

In our opinion reasonable protection can be afforded by the introduction of artificial pillars of flushed material, reinforcing the natural coal pillars to the extent of relieving them of one-third of the overburden. Such artificial pillars to be located about as follows, reference being had particularly to the plans shown in Plates 1 to 24, which are part of this report.

Owing to the great importance of substantial support for school properties, we would suggest that in each bed mined under any school, for at least 50 feet outside the lot limits, or rather for a distance equal to one-half the depth of a bed below the surface, the openings be flushed full of the best available material. The school properties—being located in all parts of the city, and over widely varying mining conditions—would afford good starting points from which to space the additional artificial pillars necessary for the protection of the surface elsewhere.

Following out the above scheme in systematic order, we would recommend the installation of artificial pillars of flushed sand or flushed culm at each street intersection where the city blocks are of the usual size, about 5 acres, the present coal pillars to remain. In the case of all coal beds of greater depth than 150 feet, such pillars,

if at the block corners, might be sufficiently near together; but for less depth the strata might be too weak to bridge the whole width of a city block, even though the usual coal pillars were left in place. Therefore it would be better, in the latter case, to install pillars in the center of each block also, in which case the pillars should each be about one-half as large as if located at the block corners only.

In locating artificial pillars intermediate between school properties, advantage should be taken of those places already flushed by the coal companies. It will be found that considerable filling of this sort has been done.

The question of the size and consequent cost of artificial piers is approached by us with much hesitation and caution, because, although we have secured considerable valuable information on the subject through the underground investigations we have been making, we know that in the last analysis the size of these piers must be estimated from the results of the testing we have done at the Fritz engineering laboratory at Lehigh University. In view of the great magnitude and importance of the question at stake, we realize that these tests, which are the first of the kind that have ever been made, are very meager and do not constitute a sufficient foundation upon which to base final conclusions.

Therefore we have decided to use a factor of safety of two. In other words, the size of the pillars we have recommended is twice as large as the tests indicate might be necessary. These tests are subject to check by further tests and other data that may be procured later, either through the working out in practice of the recommendations herein made, or otherwise, but which have not been and are not now available to us.

The size of artificial pillars should be determined by the local conditions found at the exact spot chosen upon inspection by the engineer in charge of the work. Subject to the above observations, the horizontal areas of artificial piers of flushed material confined in mine rooms are indicated in detail by the table following.

TABLE 5.—*Horizontal area, in square yards, of artificial mine pillars of confined flushed culm or flushed sand required under various permissible compressions to sustain one-third of the overburden of one city block of five acres, at various depths.*

Ultimate uniform compression permitted.	Depths.					
	25 feet.		50 feet.		100 feet.	
	Culm.	Sand.	Culm.	Sand.	Culm.	Sand.
Per cent.						
3	3,424	800	6,848	1,600	13,696	5,200
5	2,122	452	4,244	904	8,488	1,808
10	848	176	1,696	352	3,392	704
	200 feet.		400 feet.		800 feet.	
3	(a)	6,400	(a)	12,800	(a)	(a)
5	16,976	3,616	(a)	7,232	(a)	14,464
10	6,784	1,408	13,568	2,816	(a)	5,632

a Openings filled.

NOTES.—1. Up to 3 per cent compression, piers of sand and gravel concrete might be only one-half the size of sand piers, but for weights that would produce greater compression they are worthless.

2. One city block of 5 acres covers 24,200 square yards.

3. In fixing upon the amount of compression that might be permitted, consideration should be given to the fact that where several beds are to be filled, the total settlement will be several times as great as for one bed of the average thickness.

4. It will be noted that complete filling with culm is necessary for the compression mentioned at depths of 200 to about 500 feet, whereas for greater depths the compression due to the greater weight would be excessive. Sand, on account of its greater strength, is suitable for filling all beds at all depths under the city of Scranton, and is therefore to be preferred.

The location of bore holes or shafts through which to flush the material must be determined by the engineers in charge of the work. Several of the blocks can be reached from the foot of each bore hole or shaft.

In many of the beds on the west side large areas of the mines are inaccessible, and conditions are of such a character that we are thereby limited to the most general specifications. We would suggest first, that the school properties be taken as starting points, and under each of them, namely, Nos. 13, 43, 12, 29, 32, 32 annex, 14, 31, 16, 17, 18, 19, 41, 21, 40, 24, 22, 23, 25, 26, and 44, artificial piers of flushed material be installed wherever possible, these piers to extend well beyond the lot lines (at least 50 feet outside) in all the beds that have been worked, beginning with the lowest bed; and that when a pillar is built in that bed, the overlying beds be filled in order.

Early attention to schools Nos. 12, 23, and 29 is especially important. In locating the supporting pillars advantage should be taken of the large areas that are caved and closed in the Clark, New County, Big, Rock, and Diamond beds, and of other parts that are already flushed. The best results will be obtained, of course, by flushing the lowest beds first and proceeding upwards, care being taken to locate the new pillar in the upper seam over that already in place in the seam below.

COST OF SUGGESTED PROTECTIVE MEASURES.

The absence of accurate and conclusive data, and the many uncertain factors entering into this general statement make any submitted figures approximate only. Assuming that all the sources of flushing material hereinafter mentioned in the order of their importance and value—first, sand and loam brought from a distance in returning empty coal cars; second, culm from breakers and washeries; third, crushed mine rock, gob, etc.; fourth, culm and silt from Lackawanna River and Roaring Brook; fifth, crushed rock from three or four plants (which might be established by the protective commission)—are utilized in regular and systematic order, and that the methods of procuring water for flushing, etc., as suggested, are put in effect, we would in that case estimate the cost of the measures suggested about as follows:

The necessary plants and machinery for expeditiously excavating and loading the sand and filling material at distant points, and the plants in the city for unloading and transferring the material to the traction company cars for delivery at night to the various flushing points; the building of the dam and pumping stations on the Lackawanna River and the necessary storage dams at various points on the river above the city, for catching surplus sediment during seasons of high water; the dam in Roaring Brook, above the city level; the necessary means to conduct the water to the more elevated parts of the east and south sides; and a portable crushing plant to be located at the flushing points to crush the larger particles of sand, coal ashes, and city refuse that may be delivered and mixed with the flushing, would cost approximately $500,000.

The necessary facilities outlined above for the expeditious and economic handling of material and prosecution of the work having been provided, it is our opinion that artificial piers may be established in various beds at about the cost shown in the following table, using the factor of safety (2) mentioned above.

TABLE 6.—*Approximate cost per foot of coal-bed thickness of artificial mine pillar of confined flushed culm or flushed sand required under various permissible compressions to sustain one-third of the overburden of one city block of five acres, at various depths.*

Ultimate uniform compression permitted.	Cost.					
	Depth, 25 feet.		Depth, 50 feet.		Depth, 100 feet.	
	Culm.	Sand.	Culm.	Sand.	Culm.	Sand.
Per cent.						
3	$286	$266	$572	$532	$1,144	$1,064
5	176	150	352	300	704	600
10	70	60	140	120	280	240
	Depth, 200 feet.		Depth, 400 feet.		Depth, 800 feet.	
3	[a] $2,016	$2,128	(a)	$4,256	(a)	[a] $8,070
5	1,408	1,200	(a)	2,400	(a)	4,300
10	560	480	$1,120	960	(a)	1,920

[a] Filled.

The approximate cost per foot of bed thickness for each acre of complete flushing under schools and elsewhere, to take the place of pillars, if removed, would be:

For culm below level of river	$405
For sand above or below river	1,615

If, in the case of the coal beds 150 feet or more deep, the board of control concludes to be satisfied to relieve the present pillars under the schools of about one-third of the burden they now sustain, the approximate cost of so doing, per foot of bed thickness for each acre thus protected, will be about one-fifth of the cost shown in Table 6, for the same depth, material, and settlement. For example, to relieve the present pillars of the Clark bed, which is about 200 feet deep under the central city and hill sections, of one-third of the weight they now sustain, allowing 5 per cent as ultimate permissible settlement for the coal-bed roof, would cost per foot-acre of coal bed, about $280 for culm flushing, if the piers are below the river level; or $240 for sand flushing, whether above or below the river; and since this coal bed is about 7 feet thick, the total cost of such piers would be about $1,960 and $1,680 per acre, respectively.

The above table is estimated on the supposition that the pillars of flushed culm would be installed only at points that are in coal beds below the level of the river (so the necessity of pumping culm to an elevation above the river would be avoided) and that piers of flushed sand would be installed in coal beds at locations that are above the level of the river, or at any location where such sand pillars would be convenient and not more costly than culm pillars.

It will be noted that there is no large difference in cost between culm or sand. This, of course, is on account of the greater efficiency

of the sand, a less quantity of which is required to give the same supporting power.

It will be apparent that much of this work can be done by the systems of flushing already in service at the several mining plants, and that in order to accomplish the best results in the most economical manner, the plans of the city mine-cave protective commission must be made in harmony with the already established systems of the mining companies. It is manifest that all underground work should be done in cooperation with the coal companies and that the water flushed into the mines must be pumped by the plants already installed, with such additional equipment as may be found necessary.

Therefore, this matter of harmonious plans and procedure between the coal companies, the city, the school authorities, and the public is essential to the successful carrying out of any relief measures that are herein or may be hereafter suggested. It is a fact that should be evident to all that the prosperity of the city and the community is to a large extent dependent upon the coal companies, so that drastic laws or regulations that may curtail the mining of coal will necessarily react on the prosperity of the community, whereas any ameliorating plans or compromises which it may be possible to effect between the city and the mining companies tend to prolong the life of the mining industry in Scranton and vicinity, and should be promoted.

It should, therefore, be the aim of all persons interested in mine-cave protective measures and of the companies operating the mines to adopt plans that will best conserve the welfare of all concerned.

The expenditure for the work would, of course, be distributed over many years, the relief measures being applied at the points most in need of protection and as rapidly as proper arrangements could be effected and the necessary details, surveys, etc., prepared.

For the business-like carrying out of the plans suggested, it is recommended that a protective commission be established, consisting of not less than three nor more than five men representing the city authorities, the school board, and the coal companies; this commission to have full and complete authority for the execution of the plans, after approval by the proper legal action. The commission should employ an engineer as active manager of the work, who should devote all his time to the service.

GENERAL CONCLUSIONS.

In concluding this somewhat lengthy report, we are of the following opinion:

First. Speaking broadly, the surface of the city can be supported by the methods recommended, and at a cost not in any sense prohibitory when considered with relation to the value of the property and the activities for which support is absolutely essential.

Second. Although there are points in the city, as indicated in the detailed report, where at the present time in our judgment there is distinct and immediate danger to life and property, yet the total area immediately threatened constitutes but about 15 per cent of the entire area of the city, and the danger is mainly from workings in surface beds.

Third. On the west side the beds of the middle series are thick and close together and the pillars are not columnized, creating a dangerous situation where the workings have not been closed by previous caves. Particular areas thus threatened can not be definitely specified on account of the inaccessibility of much of the mined-over area. Detailed investigation should be made of the portions of the mines not already closed. Relatively, we do not believe that a large part of the territory mentioned is threatened because so much ground has been already closed by caves.

Special attention is called to the conditions under schools Nos. 13, 23, and 29. They should be attended to promptly.

The beds of the lower series, namely, the three Dunmores, are so thin and so far below the surface that with the usual system of mining we do not think they constitute a serious menace to the improvements on the surface, except along the margin of solid blocks of unmined coal and near the outcrops. In the deep-lying parts of the Dunmore beds we believe these solid blocks should be mined.

Fourth. It would seem, therefore, to be not only the part of wisdom, but absolutely obligatory to commence at once to give support to the points menaced, and thereupon proceed upon a general policy of giving support to the entire area of the city; for it must be borne in mind that with the mining activities that are constantly going on other and additional points of danger are not only liable to, but in all probability will, develop with each passing year—it might almost be said with each passing month.

Fifth. Where the owner of the surface has undoubted right to the support thereof by coal pillars, in our opinion he could permit the removal of such pillars; the value of these would under average conditions pay for such artificial support as we have recommended, assuming that the pillars were mined and the support constructed by the same operating company. This observation, however, is based upon the assumption that in such case the operating company would be one of the large transportation companies, inasmuch as while there might not be a profit in the immediate transaction of mining the pillars and installing the support there would, of course, be a profit to such companies in carrying the coal to market.

Sixth. Culm flushing should be used only in coal beds having light cover, up to 200 to 500 feet, according to the amount of settlement expected. But sand, being four or five times as strong as culm, is better, is suitable for all beds under Scranton and should be preferred.

Seventh. We believe that the conclusions adduced from the tests made, and the calculations and tabulations based thereon, are reasonably reliable; yet we desire to record the opinion that there are conditions existing in the mines to which they might not apply—for instance, in localities where several seams of coal are separated by a thin layer, or layers, of shale and slate, or even sandstone, and the pillars in the several seams are not over one another, and it is proposed reclaiming all or any part of the pillars.

Even though an application of the above tables might appear to fit the conditions, we believe that the only permissible procedure would be to first fill with flushed material all of the openings in the lowest bed of the series and then fill upward until all the beds are filled, care being taken to have the flushed areas over one another. After all of the openings in all of the seams have been filled, the pillars in the uppermost seam may then be attacked; as each pillar is removed, the space should be at once filled. No pillar reclamation should be permitted in any of the other beds until all of the pillars in the upper bed have been removed and the overburden has come to rest on the flushed material; then the pillars in the next lower seam may be attacked and handled in like manner.

NOTES ON SAND FOR MINE FLUSHING IN THE SCRANTON REGION.

By N. H. Darton.

INTRODUCTORY STATEMENT.

This report presents the results of field studies in the vicinity of the city of Scranton, Pa., to find some convenient sources of sand to be used for filling chambers in coal mines under the city. Attention was given only to material that lies at higher altitudes than the workings and might be hauled down grade or transported by water to the mines. Moreover, it was recognized that inasmuch as the final means of transportation underground would be flushing with water the material would have to be in granular condition. The sources of supply are glacial till of various kinds and the rocks of the coal measures or underlying formations. The latter would have to be quarried and crushed; the pebbles and bowlders of the till could be crushed or discarded.

ROCK FOR CRUSHING.

The entire anthracite region is underlain by rocks that contain a large proportion of sandstone suitable for crushing, and can yield an angular sand of great strength. It is estimated that sandstone of moderate hardness can be crushed into coarse sand for $0.50 to $0.60 a ton, including quarrying. This estimate is based on a cost of $1.60 per ton for coal for power.

One of the most conspicuous rocks in the Scranton region is the Pottsville conglomerate. It immediately underlies the coal measures and outcrops in belts of varying width in the mountain slopes on both sides of the coal field. The greater part of this rock is too hard to be cheaply crushed into sand. It is underlain by greenish and gray sandstones, mostly soft, and in places by red shale. These sandstones and the shale can be more easily crushed. The most extensive ledges of sandstone convenient to railroad haulage are in the gorges of Roaring Brook east of Scranton, and of Leggetts Creek, northwest of the city. Along the gorge of Roaring Brook from Moscow to Dunmore there are continuous high ledges, many of which rise 500 to 700 feet above the creek. This gorge is followed by the Erie and the Lackawanna railroads with a heavy down grade into Scranton. There are many localities favorable for the establishment of quarries and crushers, and the possible tonnage of product is practically unlimited. It is certainly sufficient to fill all coal workings

under the city of Scranton. One crushing plant is already in operation by the Nay Aug Stone Co., just below Nay Aug station. However, a large amount of stone is available farther down the gorge and therefore considerably nearer Scranton. Crushed rock from a quarry in this gorge could be loaded directly on empty coal cars and hauled down grade into Scranton.

The sandstones underlying the Pottsville conglomerate in the gorge of Leggetts Run present a thickness of about 800 feet, rising in high walls along the gorge 2 miles northwest of Providence. There is here available a very large amount of sandstone of moderate hardness, admirably located and physically well suited for sand for filling. The product could be hauled down grade on the Lackawanna Railroad or on the trolley line which follows the bottom of the gorge.

The hydraulic transportation of the fine crushed stone to the mine was not especially considered, but both on Roaring Brook and on Leggetts Creek the waters are so impounded that perhaps they are not continuously available for hydraulic work. The sandstones under the Pottsville conglomerate are exposed also in the valley of Meadow Brook in the southern part of Scranton, where they are utilized by the crusher now in operation. This crusher belongs to the Meadow Brook Co. and has a capacity of about 300 tons a day. Crushed stone from the exposures in this vicinity would be handled by the Laurel line and the Erie Railroad; possibly, also, it could be flushed down the bed of Meadow Brook, but the conditions are much less favorable for such tranportation than on Roaring Brook or Leggetts Creek.

There are extensive ledges of the sandstones of the coal measures in the high ridge extending west from Lackawanna River, just east of Holden, where a moderately large amount of gray sandstone is available. Another ledge appears on the north bank of Leggetts Creek, near its mouth. This ledge has been quarried extensively, but the quarry could be extended over 1 or 2 acres to the north. To the northwest it passes under the huge pile of culm from Leggetts Creek colliery. Sandstone ledges outcrop prominently in the high ridge on the east bank of Lackawanna River, a half mile east of Dickson, and a crusher could be established at this place with fair advantage, as the ledges are directly over extensive coal workings.

GLACIAL TILL.

The till left by the great continental glacier extends across northern Pennsylvania, and forms a mantle of irregular thickness and varying composition. In the Scranton region it covers much of the surface to a considerable depth, excepting the mountain slopes and summits, where it is thin or absent. The underlying coal-measure rocks also appear in places along the lower slopes of the

Lackawanna Valley, and near the river there are terraces of later alluvium. Where the till is thick it rises in hummocky ridges that are generally thickly strewn with bowlders. Scranton is built mostly on slopes of till, terraces of rearranged till material, and later beds of sand deposited by Lackawanna River.

The glacial till consists of a mixture of sand, clay, loam, gravel, and bowlders in varying proportion. In the Scranton region the till contains little clay and a predominance of sand, but I saw no extensive deposits of pure sand. Gravel and bowlders exist in all the exposures and their proportion is seldom less than 50 per cent. Some streaks of pure or pebbly sand occur, but they are local and would not yield a large supply. If the sandy till were subjected to washing by hydraulic jets and sluiceways the sand would all be separated from the bowlders. This till, in my opinion, is the best source of sand in the region; it can be removed at many places where the cultural and hydraulic conditions are favorable. One of the most desirable sources of supply would be from street grading, since the result would be both a large volume of sand and a city improvement. The bowlders remaining after the sand had been carried off could be crushed into sand and washed into the sluiceways.

In the northern part of Providence there are several prominent hills or knolls of sandy till which could be leveled to advantage. They lie between Bloom and Keyser Avenues, west of West Market Street; another knoll lies just east of West Market Street, north of Clark Avenue. These knolls rise from 50 to 60 feet above the average grade of the streets and would furnish nearly a half million tons of material. The material contains about 50 per cent of sand; the remainder is gravel that would have to be crushed in order to be utilized for flushing. Two very much larger masses of till lie on the mountain slope a short distance north and west of this area and another extends up the ridge on the north side of Leggetts Creek. Each of these three areas contains about a million tons of sandy till. Similar masses of till lie on the lower slopes of the mountain west of Keyser Creek, the largest one extending to within a few hundred yards of the Hyde Park colliery. There is a rock core to this largest mass, but the till is not less than 50 feet thick, and the indicated total tonnage for this one area is about 15,000,000 tons. The deposit is mostly sandy till with only a small proportion of clay; it averages nearly 50 per cent sand. The remaining material is coarse bowlders, mostly of hard rocks, which might either be crushed into sand or left on the ground after the sand is washed out. There is in this vicinity only a meager supply of water for hydraulicking.

An extensive area of sandy till is just east of the Holden colliery. It underlies land that for the greater part is not covered by buildings,

and has an estimated tonnage of about 5,000,000 tons. The material contains about 50 per cent of sand, with gravel, bowlders of hard rock, and very little clay.

One of the most desirable bodies of sandy till is on the estate of William Miles, just west of Olyphant. The land is not built on and is adjacent to various lines of railroads. A moderate amount of water is available for sluicing in a near-by creek, and water possibly can be had from the river also. The till area measures about 2,000 by 1,500 feet, and the thickness of material available is about 30 feet. These measurements indicate an aggregate of nearly 5,000,000 tons. The proportion of sand is variable, but in places it exceeds 60 per cent. It is being dug to a small extent for sand for local building purposes. There is not sufficient clay in any part of the area to be disadvantageous, and the gravel and bowlders could be crushed, if desired.

ALLUVIUM.

Along the Lackawanna River extend low alluvial terraces, which are underlain by sand that in greater part contains only a small proportion of coarse material. Unfortunately, however, the sand area near Scranton is covered with houses or is held for its value as building lots, so that the sand is not available except at a few points. As the terraces are very low, the tonnage of sand that could be obtained is not great. It is possible that the water of the river could be used for sluicing this material, but because of the great variation in the amount of water available during the different seasons of the year, the conditions are not altogether favorable. The location of the railroads along the river complicates the problem of removing the sand. Doubtless this source of material would not be as advantageous as the sandy till or crushed rock.

RIVER SAND.

The most extensive deposit of sand in the northern anthracite coal basin is under the deep valley of the Susquehanna River from Pittston to Nanticoke. Its width averages 2 miles for a long distance and its thickness varies from 100 to 200 feet in greater part. There are many places where this material could be lifted from the river channel by dredges and loaded on empty coal cars. In the river and harbor work of the United States Engineers office and in Panama Canal excavations sand is dredged from depths of 20 to 40 feet and carried in pipes 1,000 to 2,000 feet at a cost of 3 to 5 cents a cubic yard. The cost of handling sand from the Susquehanna River is a matter for local engineers to determine. The sediment brought down by the river, especially in time of flood, would rapidly refill excavations made by dredging.

APPENDIX.

COMPRESSIVE STRENGTH OF ANTHRACITE COAL.[a]

Owing to the general lack of knowledge among the engineers of the anthracite coal field as to the compressive strength of anthracite coal, and in view of the very important matters relating to the economy of mining of anthracite, which depend directly upon this subject, the Scranton Engineers' Club, in July, 1900, appointed a committee to make a general investigation of the compressive strength of anthracite coal, having reference particularly to the northern anthracite field. This table contains the results of the efforts of that committee, in a condensed form. The committee sent circular letters to the various anthracite operators in the northern field, requesting them to contribute to the efforts of the committee by sending samples in triplicate to be tested. These samples were requested in three sizes, viz.:

Two inches square on the base by 1 inch high, indicated in the table as "1."

Two inches square on the base by 2 inches high, indicated in the table as "2."

Two inches square on the base by 4 inches high, indicated in the table as "4."

These samples were requested to be prepared in each case with the base parallel to the bedding plane of the coal seam, and the height at right angles thereto.

Generous responses to this circular letter were received in the form of some 425 samples for testing, a few of which were defective and not tested. These samples were then divided and sent to the following colleges for testing, the professors named very kindly offering to assist the committee by making the tests:

To Prof. R. C. Carpenter, of the department of experimental engineering, Sibley College, Cornell University, Ithaca, N. Y., 133 samples.

To Prof. Mansfield Merriman, professor of civil engineering, Lehigh University, South Bethlehem, Pa., 177 samples.

To Prof. Louis E. Reber, dean of the school of engineering, Pennsylvania State College, State College, Pa., 113 samples.

After these samples were tested and the results returned to the committee, they were tabulated in a detailed way, forming an immense table, of which this accompanying table is a condensation. The following description of it is given, that the reader may the better understand it:

1. The collieries from which the tests were taken are arranged in the column on the left, in order, according to the location of the collieries, beginning at the northerly end of the region near Forest City and ending with the southernmost collieries from which tests were received, at Williamstown and Lykens, in the southern coal field.

2. The coal beds are arranged at the top of the table in the order of their occurrence in the measures, the highest beds being at the left, and the lowest beds at the right. Where local names for the beds differ from the general names, their local names are inserted in the body of the table.

3. The tests are arranged in vertical double columns under the several coal seams, and each test is placed in the column under its respective coal bed and in the horizontal line opposite the colliery from which it was taken.

4. Results given in this table are in pounds avoirdupois per square inch of horizontal area.

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[a] Printed by permission.

5. The items given in the columns under the coal double-bed headings are the "First crack," indicating the pressure in pounds per square inch required to produce the first crack in the sample. In other words it is the pressure which would cause the coal of the same quality as the sample to begin squeezing. The items under "Maximum load" in each case indicate the pressure in pounds per square inch at at which the sample crushed. The items under the head of "No. of tests" indicate the number of tests taken from the respective beds in the several collieries, the average of these tests being represented by the figures in the table.

6. The horizontal line headed "General average" contains the average of all the tests under the respective coal beds as indicated.

The next horizontal line under "General average" indicates the percentage of the maximum load which is represented by the pressure necessary to produce the first crack, or the squeezing pressure. And the second horizontal line under the general average shows the percentage which tests 2 and 4 bear to test 1 in each case.

The grand average, or net result, is contained under a separate heading, and indicates generally the average squeezing and crushing strength as shown by the samples tested. The tests from the several coal fields are tabulated separately, and clearly show the superior strength of the harder coals and the weakness of the softer.

7. From an inspection of this table, the following results appear to apply, approximately:

That the squeezing strength of a mine pillar whose width is twice its height is about 3,000 pounds to the square inch, and the crushing strength about 6,000 pounds per square inch, or, approximately, twice as much. And in general, other things being equal, the crushing strength of mine pillars would vary inversely as the square root of the thickness of the bed.

The same general rule apparently holds true, also, for the squeezing strength in all cases where the height of the pillar is less than its width. In tall pillars having a height greater than their width, the squeezing strength apparently remains nearly constant, while the crushing strength continues to diminish with height according to the above rule.

WM. GRIFFITH, *Chairman*. HARRY E. YEWENS,
J. H. FISHER, H. H. STOEK,
MORGAN DAVIS, Jr. J. T. BEARD,
Coal-test Committee, Scranton Engineers' Club.

Compressive strength of anthracite coal.

NORTHERN COAL FIELD.

Collieries.	Height of sample.[a]	Kidney.[b]			Olyphant No. 2, Hillman.			Diamond.			Rock.			Big Baltimore.			New County.			Clark Ross—Arch.			Dunmore Red Ash.			Dunmore No. 2.			Dunmore No. 3.			Grand average.		
		First crack.	Max. load.	No. of tests.	First crack.	Max. load.	No. of tests.	First crack.	Max. load.	No. of tests.	First crack.	Max. load.	No. of tests.	First crack.	Max. load.	No. of tests.	First crack.	Max. load.	No. of tests.	First crack.	Max. load.	No. of tests.	First crack.	Max. load.	No. of tests.	First crack.	Max. load.	No. of tests.	First crack.	Max. load.	No. of tests.	First crack.	Max. load.	No. of tests.
																	Top coal.			Bottom coal.														
Vandling[b]	1																2,971	5,663	2	1,475	8,749	3	4,423	7,531	3									
	2																2,762	4,425	2	2,569	5,239	3	2,113	7,637	3									
	4																1,800	2,787	2	1,410	2,012	3	1,975	3,318	3									
														Mills.																				
Coal Brook	1													2,901	6,187	3																		
	2													986	3,150	3																		
	4													1,200	2,079	3																		
																	Three-foot.																	
Erie	1																3,000	8,087	1	1,500	3,425	1												
	2																1,500	2,182	1	1,525	1,975	1												
	4																1,250	1,780	1	455	1,872	1												
														Grassy.																				
Jermyn, D. & H.	1													5,410	9,891	3				2,564	5,619	3												
	2													2,541	7,415	3				4,041	5,841	3												
	4													5,053	6,653	3				1,848	2,332	3												
Olyphant	1				1,825	6,026	3	2,325	5,176	2	1,822	6,316	3	2,792	6,720	3																		
	2				1,131	4,020	3	4,485	7,301	2	1,167	2,785	2	1,628	3,614	3																		
	4							1,460	3,233	3	1,536	2,565	2	3,017	3,741	2																		
Marvine	1							2,868	4,674	3				4,764	4,765	3				4,781	6,963	3												
	2							1,014	1,309	3				802	3,947	3				2,704	5,275	3												
	4							1,398	1,828	3				1,895	2,741	3				1,562	1,600	3												

[a] Test samples 2 inches square by 1 inch high indicated by 1. Test samples 2 inches square by 2 inches high indicated by 2. Test samples 2 inches square by 4 inches high indicated by 4.

[b] The coal beds are arranged in order as they occur, that is, highest on left and lowest on right. The collieries are arranged in order as located, that is, northern at top and southern at bottom. All tests in pounds per square inch.

Compressive strength of anthracite coal—Continued.

NORTHERN COAL FIELD—Continued.

Collieries.	Height of sample.	Kidney. First crack.	Kidney. Max. load.	Kidney. No. of tests.	Olyphant No. 2, Hillman. First crack.	Olyphant No. 2, Hillman. Max. load.	Olyphant No. 2, Hillman. No. of tests.	Diamond. First crack.	Diamond. Max. load.	Diamond. No. of tests.	Rock. First crack.	Rock. Max. load.	Rock. No. of tests.	Big Baltimore. First crack.	Big Baltimore. Max. load.	Big Baltimore. No. of tests.	New County. First crack.	New County. Max. load.	New County. No. of tests.	Clark Ross—Arch. First crack.	Clark Ross—Arch. Max. load.	Clark Ross—Arch. No. of tests.	Dunmore Red Ash. First crack.	Dunmore Red Ash. Max. load.	Dunmore Red Ash. No. of tests.	Dunmore No. 2. First crack.	Dunmore No. 2. Max. load.	Dunmore No. 2. No. of tests.	Dunmore No. 3. First crack.	Dunmore No. 3. Max. load.	Dunmore No. 3. No. of tests.	Grand average. First crack.	Grand average. Max. load.	Grand average. No. of tests.
D. & H., Scranton	1							2,331	3,260	2	2,319	1,266	2							2,854	6,107	2												
	2							1,454	3,011	2	1,811	3,221	2							2,545	4,251	2												
	4							1,530	2,578	2	1,346	1,630	2							2,382	3,911	2												
Leggetts Creek	1																1,869	4,882	3															
	2																1,662	2,784	2															
	4																1,279	2,832	3															
Dickson	1													3,685	6,381	3				4,113	6,274	3	2,343	3,228	3	3,821	4,821	3						
	2													3,900	5,426	3				1,575	3,001	3	1,668	4,330	3									
	4													1,657	1,819	2				865	1,720	3	1,650	2,195	3									
Cayuga	1										500	3,200	1							1,500	3,500	1												
	2										250	1,125	1							1,375	3,250	1												
	4										970	1,625	1							1,875	3,215	1												
					Four-foot.																													
Von Storch	1				5,881	6,426	3	2,500	5,000	1	2,875	5,500	1							2,750	5,462	1												
	2				2,336	4,102	3	1,500	3,500	1	1,820	4,125	1							2,250	3,960	1												
	4				1,930	2,343	3	2,500	3,200	1	3,000	3,941	1							2,250	3,045	1												
D., L. & W., Scranton	1													5,000	7,000	1	2,000	4,000	1															
	2													875	2,250	1	1,735	1,947	1															
	4													520	645	1	1,537	2,120	1															
Bellevue	1																3,500	6,875	1	2,000	5,700	1	2,500	4,500	1									
	2																3,125	4,000	1	3,625	4,990	1	2,375	3,625	1									
	4																4,315	4,625	1	1,705	2,000	1	1,500	2,000	1									
Holden	1										2,675	4,575	1				2,000	8,970	1	2,137	4,890	1												
	2										1,132	4,165	1				1,800	1,800	1	2,000	3,500	1												
	4										930	1,160	1							1,795	4,125	1												

Greenwood	1																									4,250	6,537	3						
	2																									1,937	5,704	3						
	4																									1,887	2,350	3						
Langcliffe	1																												2,201	7,041	3			
	2																												2,258	3,803	3			
	4																												2,417	3,109	3			
William "A"	1																						1,812	3,766	3	5,075	7,646	3	1,287	5,253	3			
	2																						1,262	3,020	2	1,987	5,258	3	1,775	4,062	3			
	4																						1,440	1,895	3	2,488	3,577	3	1,800	2,141	3			
Buttonwood and Plymouth								Old Bennett.			Five-foot.																							
	1	3,407	7,929	3	1,765	6,569	3	3,017	7,038	3	1,727	6,273	3	900	4,085	3																		
	2	2,847	6,216	3	1,568	2,614	3	3,127	6,306	3	2,116	2,356	3	1,700	3,544	3																		
	4	2,150	3,031	3	1,157	2,547	3	3,309	5,391	3	1,990	3,665	3	845	3,182	3																		
Avondale	1																			2,017	4,195	2	1,994	6,519	2									
	2																			1,410	2,550	2	1,732	3,519	2									
	4																			1,425	2,249	2	2,259	3,275	2									
Alden	1							2,409	5,870	2				2,562	6,160	2							2,522	5,671	2									
	2							1,285	2,279	2				1,887	2,946	2							1,587	2,368	2									
	4							2,596	3,242	2				1,937	3,179	2							1,550	2,620	2									
		George.						Mills.																										
Nanticoke	1	1,500	4,250	1	2,875	7,975	1	6,000	7,000	1				6,600	10,892	1				6,500	7,802	1	6,500	7,500	1									
	2	3,490	6,635	1	1,055	1,845	1	1,337	6,500	1				4,395	4,395	1				1,500	2,115	1	1,125	3,402	1									
	4	1,250	3,082	1	1,627	1,860	1	1,125	2,512	1				1,250	3,750	1				1,305	2,360	1	2,315	3,000	1									
General average	1	2,930	7,009	4	3,132	6,504	10	2,877	5,407	14	1,940	5,416	11	3,550	6,566	22	2,450	5,985	9	2,951	6,054	22	2,917	5,330	15	4,378	6,335	9	1,744	6,147	6	2,978	6,014	122
	2	3,008	6,321	4	1,618	3,409	10	2,122	4,144	14	1,551	2,850	10	1,990	4,266	22	2,126	3,043	8	2,402	4,157	22	1,714	4,424	14	1,957	5,480	6	2,016	3,933	6	2,025	4,087	116
	4	1,925	3,044	4	1,557	2,365	7	2,025	3,247	15	1,673	2,611	10	2,101	3,295	20	1,817	2,824	8	1,548	2,363	22	1,775	2,601	15	2,220	2,947	6	2,108	2,625	6	1,848	2,800	113
																																		351
Proportion 1: First crack ÷ max. load, i. e., percentage	1	42	100	..	49	100	..	53	100	..	36	100	..	54	100	..	41	100	..	49	100	..	57	100	..	69	100	..	28	100	..	48.4	100	...
	2	47	100	..	47	100	..	51	100	..	54	100	..	47	100	..	70	100	..	58	100	..	39	100	..	36	100	..	51	100	..	49.5	100	...
	4	63	100	..	61	100	..	50	100	..	64	100	..	64	100	..	64	100	..	65	100	..	68	100	..	75	100	..	80	100	..	65.8	100	...
Proportion 2: Tests 2 and 4 ÷ test 1, i. e., percentage	....	100	100	..	100	100	..	100	100	..	100	100	..	100	100	..	100	100	..	100	100	..	100	100	..	100	100	..	100	100	..	100.	100.	...
	....	105	90	..	52	52	..	74	77	..	80	53	..	56	65	..	87	51	..	81	69	..	56	83	..	45	86	..	115	64	..	67.	65.5	...
	....	66	40	..	51	36	..	70	67	..	86	48	..	60	50	..	70	47	..	53	39	..	58	50	..	50	46	..	121	43	..	62.1	45.7	...

Compressive strength of anthracite coal—Continued.

EASTERN MIDDLE FIELD.

Collieries.	Height of sample.	Kidney. First crack.	Kidney. Max. load.	Kidney. No. of tests.	Olyphant No. 2, Hillman. First crack.	Olyphant No. 2, Hillman. Max. load.	Olyphant No. 2, Hillman. No. of tests.	Diamond. First crack.	Diamond. Max. load.	Diamond. No. of tests.	Rock. First crack.	Rock. Max. load.	Rock. No. of tests.	Big Baltimore. First crack.	Big Baltimore. Max. load.	Big Baltimore. No. of tests.	New County. First crack.	New County. Max. load.	New County. No. of tests.	Clark Ross Arch. First crack.	Clark Ross Arch. Max. load.	Clark Ross Arch. No. of tests.	Dunmore Red Ash. First crack.	Dunmore Red Ash. Max. load.	Dunmore Red Ash. No. of tests.	Dunmore No. 2. First crack.	Dunmore No. 2. Max. load.	Dunmore No. 2. No. of tests.	Dunmore No. 3. First crack.	Dunmore No. 3. Max. load.	Dunmore No. 3. No. of tests.	Grand average. First crack.	Grand average. Max. load.	Grand average. No. of tests.
														Mammoth.						Wharton.			Buck Mt.											
Hazleton No. 5	1													5,000	6,825	1				8,500	10,525	1	7,000	10,962	1									
	2													2,830	3,547	1				4,500	5,400	1	5,000	5,000	1									
	4													1,375	1,375	1				4,000	5,990	1	5,000	3,375	1									
Hazleton No. 1	1																			1,750	5,200	2	5,488	6,528	2									
	2																			1,500	3,000	1	3,113	3,600	2									
	4																			3,057	3,170	2	3,752	4,833	2									
General average	1													5,000	6,825	1				4,000	6,975	3	5,992	8,053	3							4,996	7,417	7
	2													2,830	3,547	1				3,000	3,700	2	3,742	4,066	3							3,343	3,857	6
	4													1,375	1,375	1				3,371	4,110	3	4,135	4,347	3							3,413	3,821	7
WESTERN MIDDLE FIELD.																																		
														Mammoth.						Seven foot.			Buck Mt.											
Packer No. 3	1													3,000	9,892	1				1,552	9,500	1	4,450	6,500	1							3,001	8,631	3
	2													895	4,000	1				500	4,497	1	968	2,000	1							788	3,499	3
	4													1,945	2,500	1				1,370	3,000	1	1,005	1,842	1							1,440	2,447	3
SOUTHERN FIELD.																																		
														No. 9½ White Ash.			No. 9 White Ash.			No. 7 White Ash.			White's Vein.			Lykens Valley.			Little Lykens Valley.					
Williamstown	1													1,442	3,638	2	2,063	4,509	2	897	3,571	2												
	2													1,087	2,191	2	1,753	3,219	2	860	1,596	2												
	4													1,515	2,152	2	841	1,150	2	1,361	3,127	2												
Lykens	1																						642	4,013	2	725	4,131	2	976	3,025	2	1,124	3,814	12
	2																						1,175	2,120	2	956	2,937	2	764	1,198	2	1,099	2,377	12
	4																						1,231	1,612	2	1,246	2,262	2	735	911	2	988	1,809	12
																																		416

COMPRESSIVE STRENGTH OF MATERIALS FOR ROOF SUPPORT.

A series of tests of various kinds of materials for supporting the roof in mine workings was made in the Fritz Engineering Laboratory at Lehigh University. The results are given in the following report:

South Bethlehem, Pa., *January 26, 1911.*

Messrs. William Griffith and Eli T. Conner,

Scranton, Pa.

Gentlemen: I beg leave to state that we have concluded the series of tests on the bearing power of materials used in sustaining the roofs of mines, and beg leave to report as follows.

With the exception of a small quantity of sand, all of the materials which we tested were received from you, there being one carload which you sent us from the anthracite coal-mining district. The detailed descriptions of the various tests follow:

TEST NO. 1.

This test consisted of crushing a pillar made of mine rock, the four sides of which were laid vertically and then filled with stone of various sizes packed in by hand so as to make a pillar of loose stones without mortar of any kind. This pillar was 5 feet long, 2 feet 4 inches wide, and 18 inches high. It was laid directly on the bedplate of the testing machine and under three steel beams which were later used in applying the load over the entire top surface of the pillar. The stone used was slate, bony coal, and fire clay. The load on this pillar was applied in increments until a maximum pressure of 489,150 pounds was reached. The following table shows the loading at the different stages of the tests, together with the deflections caused by these loads. You will notice that when the total load was 489,150 pounds (approximately 42,000 pounds per square foot) the maximum compression amounted to 5.3 inches.

TEST NO. 2.

Loads and settlements of a rectangular pillar of mine rock.

Loads.	Settlements.	Loads.	Settlements.	Loads.	Settlements.
Pounds.	*Inches.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*
4,950	....	78,625	2.21	260,450	3.95
18,550	0.52	104,050	2.74	326,450	4.32
33,750	.97	130,350	3.15	396,940	4.83
46,350	1.40	233,200	3.75	489,150	5.26
63,025	1.81				

This test consisted in crushing a timber crib made of four layers of round timbers which were about 5 inches in diameter and were laid log-house fashion. Each of two of the layers consisted of two of those round timbers 5 feet 4 inches in length and each of the other two layers consisted of three round timbers 2 feet 8 inches in length. The spaces between these timbers were filled with slate, bony coal, and fire clay, and the crib was then filled with small stones shoveled in; the whole resulting in a timber crib 5 feet 4 inches in length, 2 feet 8 inches wide, and 23½ inches high. The load was applied in increments as shown by the following table. The maximum load reached 900,000 pounds and the maximum settlement was 7.1 inches.

Loads and settlements of a timber crib filled with mine rock.

Loads.	Settlements.	Loads.	Settlements.	Loads.	Settlements.
Pounds.	*Inches.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*
5,250	....	120,000	2.13	463,000	4.86
10,550	0.49	140,000	2.33	506,000	5.23
20,000	.78	179,800	2.72	604,000	5.80
30,000	1.02	220,000	3.09	669,000	6.10
40,200	1.21	260,000	3.44	728,600	6.38
60,200	1.48	310,000	3.80	780,000	6.71
80,400	1.74	370,000	4.17	800,000	6.87
100,000	1.95	413,000	....	900,000	7.08

TEST NO. 3.

This test consisted of crushing a circular pillar 28 inches in diameter and 14½ inches high, made of slate arranged so that the outer surface was fairly smooth, the spaces between the stones and the interior of the pillar being filled with small stones. The load was applied in increments as shown in the following table, the maximum load being 361,000 pounds, with a corresponding settlement of 4½ inches.

Loads and settlements of a circular pillar of mine rock.

Loads	Settlements.	Loads.	Settlements.	Loads.	Settlements.
Pounds.	*Inches.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*
4,000	....	71,200	1.29	195,400	3.15
20,000	0.19	98,000	1.48	238,500	3.69
37,000	.65	127,000	1.72	276,000	4.05
51,000	.75	150,000	2.50	361,600	4.51
60,200	1.08	183,000	2.82		

After tests Nos. 1, 2, and 3 the stones were found to be very badly crushed, many having been reduced almost to a powder, especially those immediately under the load.

TEST NO. 4.

This test consisted in loading a pile of broken stones and observing the settlement caused by the loading. The stone used was crushed sandstone which would pass through a ring 1¾ inches in diameter; it had 40 per cent voids, but under the bearing plate on which the load was applied the voids were filled with small broken stones so as to get a secure bearing. The pile of stone was 25 inches wide, 9½ inches high, 2 feet 10 inches long on the top, and 4 feet 5 inches long on the bottom. The load was applied on a cast-iron bearing plate 20 inches square which rested on the top of the pile of stones. The following table gives the loads and the settlement. The maximum load reached was 581,000 pounds, and the maximum settlement was 4.4 inches:

Loads and settlements of a pile of crushed sandstone.

Loads.	Settlements.	Loads.	Settlements.	Loads.	Settlements.
Pounds.	*Inches.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*
1,400	....	44,000	1.73	292,000	3.73
2,450	....	81,400	2.38	437,000	4.10
21,000	0.87	141,700	2.97	581,000	4.36

After the test many of the stones were found reduced practically to a powder. The stones under the bearing plate were greatly disintegrated and the plate was pressed downward into the stones. At the ends the pile moved outward as the load was applied, but on the sides the pile was confined by timbers which prevented lateral movement.

TEST NO. 5.

This test consisted in crushing a pile of broken sandstone of various sizes up to pieces as large as a man's head. Small stones were placed under the bearing plate. The stones were confined on the sides but were free on the ends and were not laid in any order. The pile was 25 inches wide and 11¼ inches high; its length was 3 feet 8 inches on top and 5 feet at the bottom. The load was applied by a cast-iron bearing plate on the top of the pile, the plate being 20 inches square. The following table gives the loads and settlements. The maximum load was 417,000 pounds and the maximum settlement was 4.6 inches.

Loads and settlements of a pile of broken sandstone.

Loads.	Settlements.	Loads.	Settlements.	Loads.	Settlements.
Pounds.	*Inches.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*
6,500	....	50,000	1.06	194,300	3.21
21,000	0.32	72,500	1.54	266,000	3.74
25,000	.46	155,500	2.35	365,000	4.31
31,500	.61	164,400	2.66	417,000	4.61
33,000	.69				

TEST NO. 6.

This test consisted of applying a load to a pile of river sand by means of a 20 by 20 inch bearing plate. The pile was 8 inches deep, 2 feet 6 inches long on top, and 4 feet 2 inches long on the bottom, had a width of 25 inches, and was confined on the sides but not on the ends. The maximum load reached was 600,000 pounds, and the maximum settlement was 5 inches.

TEST NO. 7.

This test consisted in crushing a pile of broken sandstone, the pile having 40 per cent voids and being of sizes that would pass through a ring 1¾ inches in diameter, mixed with river sand in proportions of ten volumes of the broken stone and four volumes of sand. The pile was 10½ inches in depth, 25 inches wide, 2 feet 5 inches long on top, and 4 feet 6 inches long at the bottom; it was confined on the sides but not on the ends. The load was applied on top of the pile through a 20 by 20 inch bearing plate. The following table shows the loads and settlements. The maximum load was 800,000 pounds and the maximum settlement was 4.7 inches.

Loads and settlements of a pile of broken stone and sand.

Loads.	Settlements.	Loads.	Settlements.	Loads.	Settlements.
Pounds.	*Inches.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*
2,550	....	100,000	2.41	488,000	4.13
13,000	0.67	180,000	3.02	640,000	4.43
27,300	1.27	249,700	3.39	8001000	4.69
52,300	1.82	337,600	3.73		

TEST NO. 8.

In this test a cast-iron cylinder was filled with coal culm flushed in with water. A piston was then placed on top of the culm and the whole was allowed to stand on a boiler for two days; the cylinder was then placed in the testing machine and pressure was applied to the piston, which in turn communicated the pressure to the culm. within the cylinder. The inside dimensions of the cylinder were as follows: Diameter, $6\frac{3}{8}$ inches; depth, $10\frac{3}{8}$ inches. The depth of the culm in the cylinder was 10 inches. The pressure was applied to the piston and the culm was compressed until the settlement reached 2.7 inches under a load of 200,000 pounds. This load corresponds to a pressure of 6,150 pounds per square inch or 443 short tons per square foot. The loads and settlements are given in the following table:

Loads and settlements of wet coal culm confined in a cast-iron cylinder.

Loads.	Settlements.	Loads.	Settlements.	Loads.	Settlements.
Pounds.	*Inches.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*
100	....	10,100	0.66	55,400	1.82
1,100	0.10	12,100	.76	65,000	1.94
2,100	.19	14,100	.85	75,000	2.04
3,100	.27	16,100	.93	85,400	2.13
4,100	.32	18,100	1.01	95,000	2.21
5,100	.36	20,100	1.07	106,300	2.32
6,100	....	25,100	1.22	124,670	2.40
7,100	.43	30,100	1.34	150,000	2.44
8,100	.58	35,100	1.45	200,000	2.73
9,100	.63	45,000	1.66		

TEST NO. 9.

This test consisted in applying pressure to the piston of a cast-iron cylinder in the same manner as in test No. 8, but the cylinder was filled with broken dry sandstone instead of coal culm. This broken sandstone had 40 per cent voids, and the pieces would all pass through a ring $1\frac{3}{4}$ inches in diameter. The cylinder was filled to the top, giving a depth of stone of $10\frac{7}{16}$ inches. The maximum load applied was 300,000 pounds, which caused a settlement of $3\frac{1}{2}$ inches, or 9,200 pounds per square inch. As a result of the test, the stone was completely crushed and compressed into the iron cylinder so that it had to be cut out with a chisel. The loads and settlements for this test follow:

Loads and settlements of broken sandstone confined in a cast-iron cylinder.

Loads.	Settlements.	Loads.	Settlements.	Loads.	Settlements.
Pounds.	*Inches.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*
100	....	16,000	1.79	75,000	2.91
2,000	0.46	18,000	1.89	100,000	3.07
4,000	.72	20,000	1.94	125,000	3.18
6,000	1.10	25,000	2.15	150,000	3.28
8,000	1.30	30,000	2.32	175,000	3.35
10,000	1.43	35,000	2.42	225,000	3.51
12,000	1.56	40,000	2.52	275,000	3.55
14,000	1.69	50,000	2.67	300,000	3.56

TEST NO. 12.

This test was similar to test No. 8 except that the cylinder filled with the culm was allowed to stand, with the piston removed, for eight days over a boiler. The culm was 9 inches deep in the cylinder, and the pressure was applied to the piston until the settlement reached 3 inches under a load of 300,000 pounds. This load corresponds to a pressure of 9,200 pounds per square inch. Although the culm had been drying for eight days, there was considerable water in it; the water was squeezed out during the test. The loads and settlements for this test follow.

Loads and settlements of damp culm confined in a cast-iron cylinder.

Loads.	Settlements.	Loads.	Settlements.	Loads.	Settlements.
Pounds.	*Inches.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*
500	....	20,000	1.216	150,000	2.631
1,000	0.057	30,000	1.501	200,000	2.762
2,000	.175	40,000	1.708	250,000	2.876
5,000	.452	50,000	1.871	300,000	2.999
10,000	.786	75,000	2.168		
15,000	1.025	100,000	2.373		

TEST NO. 13.

This test was exactly similar to test No. 8, except that the cast-iron cylinder was filled with dry Delaware River sand; the sand was placed in the cylinder and settled by shaking until it was flush with the top. The load was then applied to the piston until a maximum pressure of 300,000 pounds, with a corresponding settlement of 3.4 inches, was reached. The table showing loads and settlements follows.

Loads and settlements of dry Delaware River sand confined in a cast-iron cylinder.

Loads.	Settlements.	Loads.	Settlements.	Loads.	Settlements.
Pounds.	*Inches.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*
100	....	20,000	1.22	150,000	2.75
500	0.13	30,000	1.46	175,000	2.89
1,000	.25	40,000	1.66	200,000	3.01
2,000	.41	50,000	1.83	250,000	3.20
5,000	.65	75,000	2.15	300,000	3.35
10,000	.89	100,000	2.39		
15,000	1.07	125,000	2.59		

TEST NO. 10.

This test consisted in applying pressure to the piston of the cylinder in the same manner as in test No. 9; the broken sandstone had 40 per cent voids; the pieces would all pass through a ring $1\frac{3}{4}$ inches in diameter, and all voids were filled with river sand. The cylinder was filled to the top, giving the mixture of stone and sand a depth of $10\frac{7}{16}$ inches. The maximum load applied was 300,000 pounds, or 9,200 pounds per square inch, which corresponded to a settlement of 2.4 inches. As a result of the test the stone was completely crushed and compacted in the iron cylinder. Loads and settlements for the test follow.

Loads and settlements of a mixture of broken sandstone and river sand confined in a cast-iron cylinder.

Loads.	Settlements.	Loads.	Settlements.	Loads.	Settlements.
Pounds.	*Inches.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*
100	....	10,000	1.01	75,000	1.83
1,000	0.25	15,000	1.16	100,000	1.95
2,000	.46	20,000	1.27	150,000	2.12
4,000	.66	30,000	1.43	200,000	2.25
6,000	.84	40,000	1.55	250,000	2.34
8,000	.95	50,000	1.65	300,000	2.42

TEST NO. 11.

This test consisted in applying a pressure to the piston of the cylinder in the same manner as in test No. 9; but cinders, formed by burning anthracite coal under boilers, were used in the cylinder instead of culm. The cylinder was filled to the top with the cinders, which had 64 per cent voids. The maximum load applied was 300,000 pounds, or 9,200 pounds per square inch, corresponding to a settlement of 5.3 inches. The loads and settlements for this test follow:

Loads and settlements for anthracite-coal cinders confined in a cast-iron cylinder.

Loads.	Settlements.	Loads.	Settlements.	Loads.	Settlements.
Pounds.	*Inches.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*
100	....	10,000	2.85	100,000	4.74
700	0.45	14,000	3.23	150,000	4.98
1,400	.93	20,000	3.55	200,000	5.14
2,400	1.38	34,100	3.99	250,000	5.25
4,000	1.89	60,000	4.41	300,000	5.33
6,000	2.34				

TEST NO. 14.

Pure sand was flushed into a cylinder. The sand was allowed to dry for a period of 48 hours. The top of the sand was 1⅛ inches below the top of the cylinder.

The following are the results of the test:

Loads and tests of Delaware River sand confined in a cylinder.

Loads.	Settlements.	Loads.	Settlements.	Loads.	Settlements.
Pounds.	*Inches.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*
650	....	40,000	0.56	160,000	1.39
2,000	0.05	50,000	.67	175,000	1.51
5,000	.12	75,000	.90	200,000	1.60
10,000	[a].21	100,000	1.00	250,000	1.79
20,000	.31	125,000	1.25	300,000	1.93
30,000	.46				

[a] Water appeared on surface of sand.

TEST NO. 15.

A pile of blue coal measures sandstone, in pieces 3 inches to 6 inches square, the pile measuring 20¼ inches wide, 3 feet 3 inches long on the top, and 9 inches deep, voids on top filled with a small quantity of broken Potsdam sandstone for bearing. On the sides the 3 feet 3 inches dimension was confined by 6-inch by 8-inch timbers; the base plate of the machine and the **I** beams confined the material on the top and bottom. On the ends the material was free to move outward, but in the test there was very little movement at the ends. The loads were applied to the top of the pile in increments, and the maximum load reached was 600,000 pounds.

The following table gives the loads and the settlements corresponding thereto:

Table of loads and settlements.

Loads.	Settlements.	Loads.	Settlements.	Loads.	Settlements.
Pounds.	*Inches.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*
3,100	....	80,000	0.81	232,000	1.56
6,000	....	90,000	.88	305,000	1.57
8,000	0.06	100,000	.93	321,700	1.67
10,000	.12	110,000	.95	352,000	1.76
15,000	.18	120,000	1.00	375,000	1.82
20,000	.255	140,000	1.06	395,000	1.89
25,000	.325	162,000	1.15	425,000	1.97
30,000	.375	180,200	1.25	460,000	2.05
41,000	.48	201,500	1.30	500,000	2.10
50,000	.55	286,000	1.38	525,000	2.17
60,000	.62	240,000	1.43	554,000	2.25
70,000	.73	260,000	1.48	600,000	[a] 2.43

[a] This settlement is equivalent to 27 per cent.

Yours, very truly,

FRANK P. McKIBBEN.

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